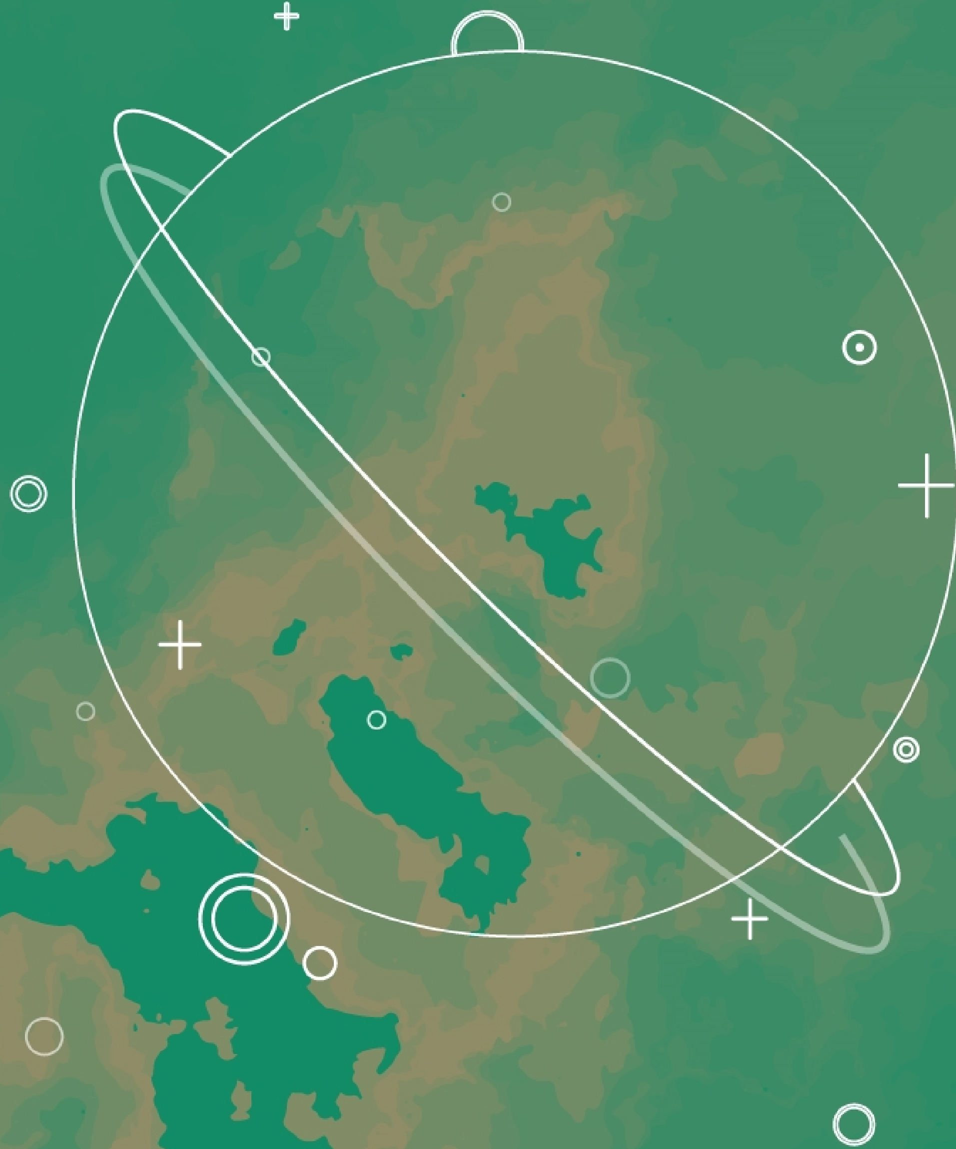


CHAPTER 1

Skills For Science

CONTENTS

August 27, 2021

This book deals with the physical sciences - physics and chemistry. All the sciences are based on the use of experiment and testing to understand the world around us better. The scientific method requires us to constantly re-examine our understanding, by testing new evidence with our current theories and making changes to those theories if the evidence does not meet the test. The scientific method therefore is the powerful tool you will use throughout the physical sciences.

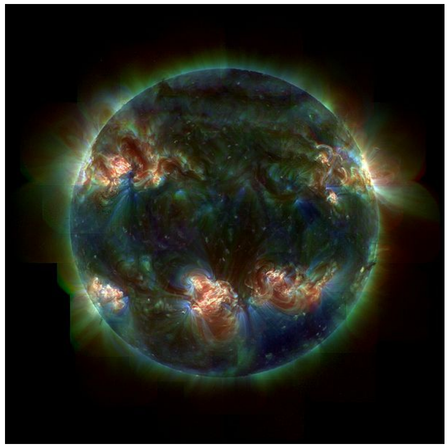


Figure 1: An ultraviolet image of the Sun.

In this chapter you will learn how to gather evidence using the scientific method. These skills will then be used throughout this textbook to test scientific theories and practices.

1 THE DEVELOPMENT OF A SCIENTIFIC THEORY

The most important, and most exciting, thing about science and scientific theories is that they are not fixed. Hypotheses are formed and carefully tested, leading to scientific theories that explain those observations and predict results. **The results are not made to fit the hypotheses**. If new information comes to light with the use of better equipment, or the results of other experiments, this new information is used to improve and expand current theories. If a theory is found to have been incorrect it is changed to fit this new information. The data should never be made to fit the theory, if the data does not fit the theory then the theory is reworked or discarded. Although this changing of opinion is often taken for inconsistency, it is this very willingness to adapt that makes science useful, and allows new discoveries to be made.

Remember that the term theory has a different meaning in science. A **scientific theory** is not like your theory of about why you can only ever find one sock. A scientific theory is one that has been tested and proven through repeated experiment and data. Scientists are constantly testing the data available, as well as commonly held beliefs, and it is this constant testing that allows progress, and improved theories.

1.1 Gravity

The theory of gravity has been slowly developing since the beginning of the 16th century. Galileo Galilei is credited with some of the earliest work. At the time it was widely believed that heavier objects accelerated faster toward the earth than light objects did. Galileo had a hypothesis that this was not true, and performed experiments to prove this.

Galileo's work allowed Sir Isaac Newton to hypothesise not only a theory of gravity on earth, but that gravity is what held the planets in their orbits. Newton's theory was used by John Couch Adams and Urbain Le Verrier to predict the planet Neptune in the solar system and this prediction was proved experimentally when Neptune was discovered by Johann Gottfried Galle.

Although a large majority of gravitational motion could be explained by Newton's theory of gravity, there were things that did not fit. But although a newer theory that better fit the facts was eventually proved by Albert Einstein, Newton's gravitational theroy is still successfully used in many applications where the masses, speeds and energies are not too large.

1.2 Thermodynamics

The principles of the three rules of thermodynamics describe how energy works, on all size levels (from the workings of the Earth's core, to a car engine). The basis for these three rules started as far back as 1650 with Otto von Guericke. He had a hypothesis that a vacuum pump could be made, and proved this by making one. In 1656 Robert Boyle and Robert Hooke used this information and built an air pump.

FACT

Robert Boyle should be a familiar name to you. Boyle's law came about from his air pump experiments, where he discovered that pressure is inversely proportional to volume at a constant temperature (p $\propto \frac{1}{V}$ at constant T).

Over the next 150 years the theory was expanded on and improved. Denis Papin built a steam pressuriser and release valve, and designed a piston cylinder and engine, which Thomas Savery and Thomas Newcomen built. These engines inspired the study of heat capacity and latent heat. Joseph Black and James Watt increased the steam engine efficiency and it was their work that Sadi Carnot (considered the father of thermodynamics) studied before publishing a discourse on heat, power, energy and engine efficiency in 1824.

This work by Carnot was the beginning of modern thermodynamics as a science, with the first thermodynamics textbook written in 1859, and the first and second laws of thermodynamics being determined in the 1850s. Scientists such as Lord Kelvin, Max Planck, J. Willard Gibbs (all names you should recognise) among many many others studied thermodynamics. Over the course of 350 years thermodynamics has developed from the building of a vacuum pump, to some of the most important fundamental laws of energy.

2 SCIENTIFIC METHOD

The scientific method is the basic skill process in the world of science. Since the beginning of time humans have been curious as to why and how things happen in the world around us. The scientific method provides scientists with a well structured scientific platform to help find the answers to their questions. Using the scientific method there is no limit as to what we can investigate. The scientific method can be summarised as follows:

1. Ask a question about the world around you.
2. Do background research on your questions.
3. Make a hypothesis about the event that gives a sensible result. You must be able to test your hypothesis through experiment.
4. Design an experiment to test the hypothesis. These methods must be repeatable and follow a logical approach.
5. Collect data accurately and interpret the data.You must be able to take measurements, collect information, and present your data in a useful format (drawings, explanations, tables and graphs).
6. Draw conclusions from the results of the experiment. Your observations must be made objectively, never force the data to fit your hypothesis.
7. Decide whether your hypothesis explains the data collected accurately.
8. If the data fits your hypothesis, verify your results by repeating the experiment or getting someone else to repeat the experiment.
9. If your data does not fit your hypothesis perform more background research and make a new hypothesis.

Remember that in the development of both the gravitational theory and thermodynamics, scientists expanded on information from their predecessors or peers when developing their own theories. It is therefore very important to communicate findings to the public in the form of scientific publications, at conferences, in articles or TV or radio programmes. It is important to present your experimental data in a specific format, so that others can read your work, understand it, and repeat the experiment.

1. Aim: A brief sentence describing the purpose of the experiment.
2. Apparatus: A list of the apparatus.
3. Method: A list of the steps followed to carry out the experiment.
4. Results: Tables, graphs and observations about the experiment.
5. Discussion: What your results mean.
6. Conclusion: A brief sentence concluding whether or not the aim was met.

2.1 A hypothesis

A hypothesis should be specific and should relate directly to the question you are asking. For example if your question about the world was, why do rainbows form, your hypothesis could be: Rainbows form because of light shining through water droplets. After formulating a hypothesis, it needs to be tested through experiment. An incorrect prediction does not mean that you have failed. It means that the experiment has brought some new facts to light that you might not have thought of before.

ACTIVITY

Designing your own experiment

Recording and writing up an investigation is an integral part of the scientific method. In this activity you are required to design your own experiment. Use the information provided below, and the flow diagram in the previous experiment to help you design your experiment.

The experiment should be handed in as a $1-2$ page report. Below are basic steps to follow when designing your own experiment.

1. Ask a question which you want to find an answer to.
2. Perform background research on your topic of choice.
3. Write down your hypothesis.
4. Identify variables important to your investigation: those that are relevant, those you can measure or observe.
5. Decide on the independent and dependent variables in your experiment, and those variables that must be kept constant.
6. Design the experiment you will use to test your hypothesis:
    - State the aim of the experiment.
    - List the apparatus (equipment) you will need to perform the experiment.
    - Write the method that will be used to test your hypothesis
        - in bullet format
        - in the correct sequence, with each step of the experiment numbered.
    - Indicate how the results should be presented, and what data is required.

ACTIVITY (continued)

Analysis of the scientific method.

Break into groups of 3 or 4 and study the flow diagram provided, then discuss the questions that follow.

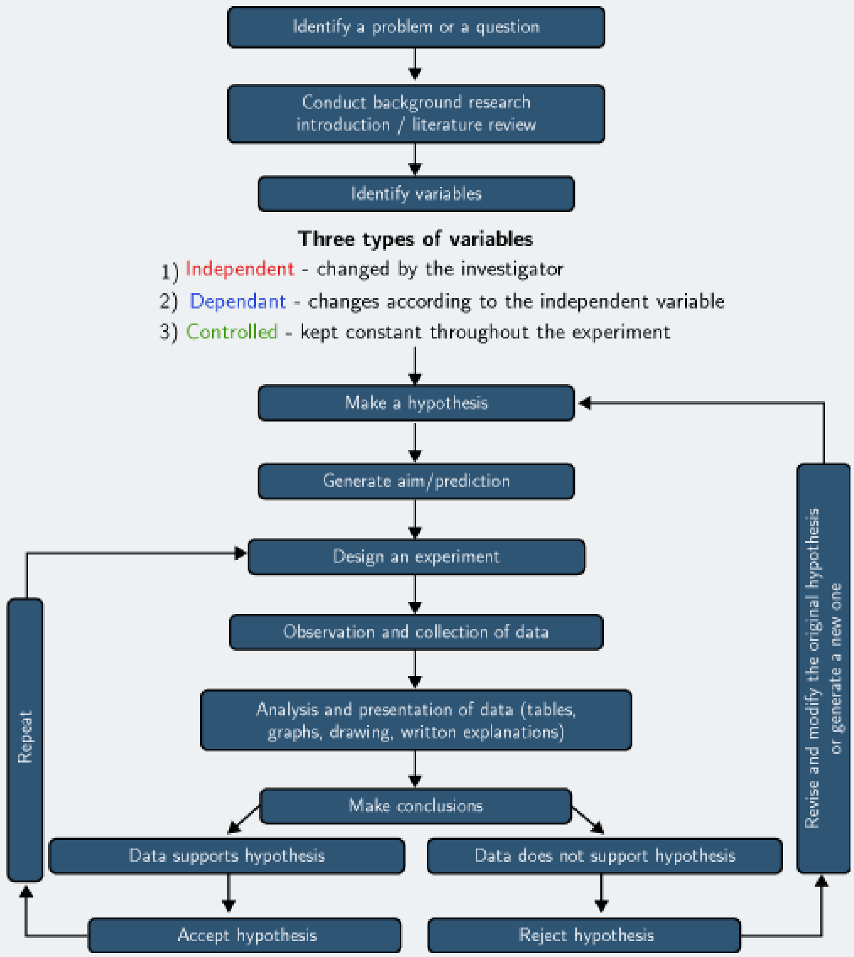


Figure 2: Overview of scientific method.

1. Once you have a problem you would like to study, why is it important to conduct background research before doing anything else?
2. What is the difference between a dependent, independent, and controlled variable and why is it important to identify them?
3. What is the difference between identifying a problem, a hypothesis, and a scientific theory?
4. Why is it important to repeat your experiment if the data fits the hypothesis?

2.2 Reading instruments

Before you perform an experiment you should be comfortable with certain apparatus that you will be using. The following pages give some commonly used apparatus and how to use them.

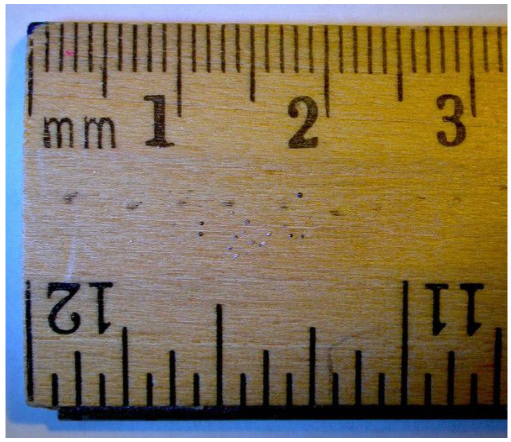


Figure 3: The end of a ruler

Most rulers you find have two sets of lines on them. You can ignore those with the numbers spaced further apart. We only work in the metric system and those are for the imperial system. The closest together lines are for millimetres, the thicker lines are for 5 mm and the thicker, longer lines with numbers next to them mark off every 10 mm $(1$ cm$)$.

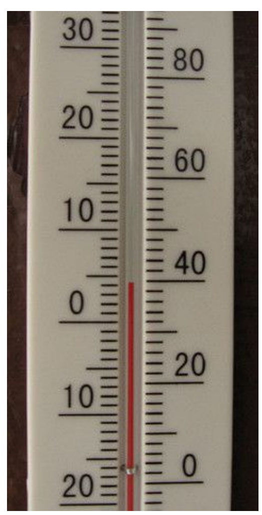


Figure 4: Reading a thermometer.

A thermometer can have one, or two sets of numbers on it. If it has two sets of numbers one will be in Celsius, and one will be in Fahrenheit. We use Celsius, so you can ignore the side with a larger temperature range. In Figure 4 you can ignore the right-hand side. Looking on the left you can see that the red line (coloured ethanol here) is next to the fourth line above 0 °C . Each small line is 1 °C so the temperature is 4 °C.

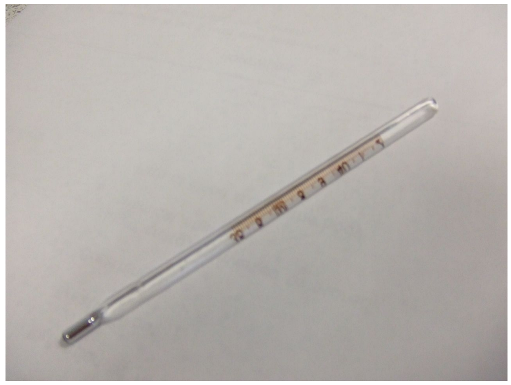


Figure 5: A laboratory style thermometer.

Laboratory thermometers will go to much higher temperatures than those used for measuring the temperature outside, or your body temperature. It is important to make sure that the thermometer you are using can handle the temperature you will be measuring. If not, do not use that thermometer as you will break it. Make sure your thermometer is upright whenever you use it in an experiment, to avoid incorrect results.

Figure 6: A scale (also referred to as a balance).

Different scales have different functions. However, a basic function of all scales is a **tare** button. This zeros the balance. It is important that you zero the balance before you take any measurements. If you are weighing something on a piece of paper you should tare the balance with the piece of paper on it, and weigh the substance. Make sure you check the units that your scale is weighing in. If you want your value to be accurate to $,00$ g then the scale must measure to that accuracy. A scale that measures in mg would be best.

A burette is used to accurately measure the volume of a liquid added in an experiment. The valve at the bottom allows the liquid to be added drop-by-drop, and the initial and final volume can be measured so that the total volume added is known.

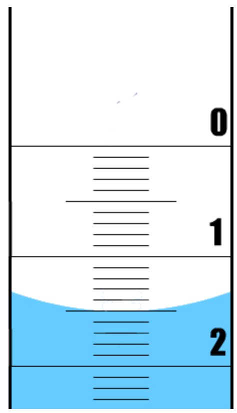


Figure 7: The meniscus of water in a burette.

The surface of the water (the *meniscus*) is slightly higher at the edges of a container than in the middle. This is due to surface tension and the interaction between the water and the edge of the container (Figure 7). When measuring the volume in a burette (or measuring cylinder or pipette) you should look at the bottom of the meniscus. Where that lies is where you measure the volume. So in this example the meniscus is on the fifth line below the large line that represents 1ml. Therefore the volume is $1,5$ml.

It is also possible that the liquid being measured has greater internal forces than those between it and the container. Then the meniscus would be higher in the middle than at the sides, and you would use the top of the meniscus to measure your volume.

Figure 8: A measuring cylinder with water.

A measuring cylinder is used to measure volumes that you want accurate to the nearest millilitre or so. It is not a highly accurate way of measuring volumes. The volume in a measuring cylinder is measured in the same way as for a burette, the difference is that in a measuring cylinder the smallest volume would be at the bottom, while the largest would be at the top.

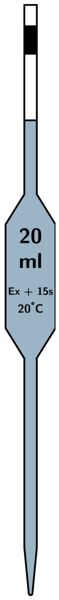


Figure 9: A 20 ml volumetric pipette.

Figure 10: A graduated pipette

There are two types of pipettes you might encounter this year. A volumetric pipette has a large bulb, marked with the set volume it can measure. Above the bulb on these pipettes there is a line. For a 5 ml volumetric pipette, when the meniscus of your liquid sits on the line, then the volume in that pipette is 5 ml.

A graduated pipette has the same type of markings you see on a burette. The top is 0ml, and the volume increases as you move down the pipette. In this pipette you should fill the pipette to near the 0ml line and make a note of the volume. You can then add the desired volume, stopping when the volume in the pipette has decreased by the required amount.

2.3 Performing experiments

A learner wondered whether the rate of evaporation of a substance was related to the boiling point of the substance. Having done background research they realised that the boiling point of a substance is linked to the intermolecular forces within the substance. They know that more energy is required to overcome stronger intermolecular forces. This led them to form the following hypothesis:

The larger the intermolecular forces of a substance, the higher the boiling point. Therefore, if a substance has a high boiling point it will have a slower rate of evaporation.

Perform the general experiment that the learner designed to test that hypothesis.

GENERAL EXPERIMENT

Boilling points and rate of evaporation: Part 1

Aim

To determine whether the rate of evaporation of a substance is related to its boiling point.

Apparatus

You will need the following items for this experiment:

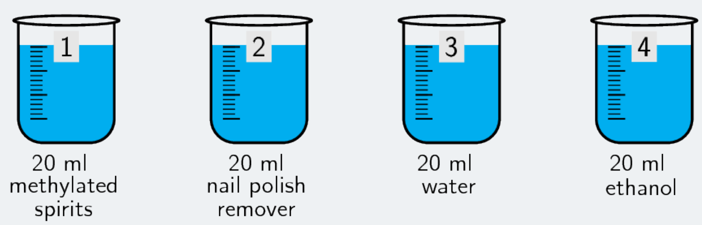
- 220 ml water, 20 ml methylated spirits, 20 ml nail polish remover, 20 ml water, 20 ml ethanol
- One 250 ml beaker, four 20 ml beakers, a thermometer, a stopwatch or clock

Method

WARNING

All alcohols are toxic, methanol is particularly toxic and can cause blindness, coma or death. Handle all chemicals with care.

1. Place 200 ml of water into the 250 ml beaker and move the beaker to sunny spot. Place the thermometer in the water.
2. Label the four 20 ml beakers $1-4$. These beakers should be marked.
3. Place 20 ml methylated spirits into beaker 1, 20 ml nail polish remover into beaker 2, 20 ml water into beaker 3 and 20 ml ethanol into beaker 4.



4. Carefully move each beaker to the warm (sunny) spot.
5. Observe each dish every two minutes. Note the volume in the beaker each time.
6. Continue making observations for 20 minutes. Record the volumes in a table.

GENERAL EXPERIMENT (continued)

Results

- Record your observations in a table like the one below.

Substance	**Methylated spirits**	**Nail polish remover**	**Water**	**Ethanol**
Boiling point ($°C$)	$78{,}5$	$56{,}5$	100	$78{,}4$
Initial volume (ml)	20	20	20	20
2 min				
4 min				
6 min				

3 DATA AND DATA ANALYSIS

In order to analyse the data obtained during experiments it is often necessary to convert that data into different representations. One type of representation is a graph. A few examples are given here.

3.1 How to draw graphs in science

For all graphs plotted from experimental data it is important to remember that you should never *connect the dots*. Data will never follow a line or curve perfectly. By obtaining multiple experimental data points any discrepancies in each data point can be removed. The line added after the points are plotted should be a **best fit line**, it can be used to determine further information.

Features of graphs you plot:

- An appropriate scale is used for each axis so that the plotted points use most of the axis/space (work out the range of the data and the highest and lowest points).
- The scale must **remain the same** along the entire axis and should use easy intervals such as 10's, 20's, 50's. Use graph paper for accuracy.
- Each axis must be labelled with what is shown on the axis and must include the appropriate units in brackets, e.g. Temperature $(°\text{C})$, time (seconds), height (cm).
- The independent variable is generally plotted along the x-axis, while the dependent variable is generally plotted along the y-axis.
- Each point has an x and y co-ordinate and is plotted with a symbol which is big enough to see, e.g. a cross.
- A best fit line is then added to the graph.
- **Do not** start the graph at the origin unless there is a data point for $(0, 0)$, or if the best fit line runs through the origin.
- The graph must have a clear, descriptive title which outlines the relationship between the dependent and independent variable.
- If there is more than one set of data drawn on a graph, a different symbol (and/or colour) must be used for each set and a key or legend must define the symbols.
- Use line graphs when the relationship between the dependent and independent variables is continuous.
- For a line graph, you can draw a line of best fit with a ruler. The number of points are distributed fairly evenly on each side of the line (see Figure 11).
- With an exponential graph (when the points appear to be following a curve) you can draw a best fit line freehand (see Figure 12).

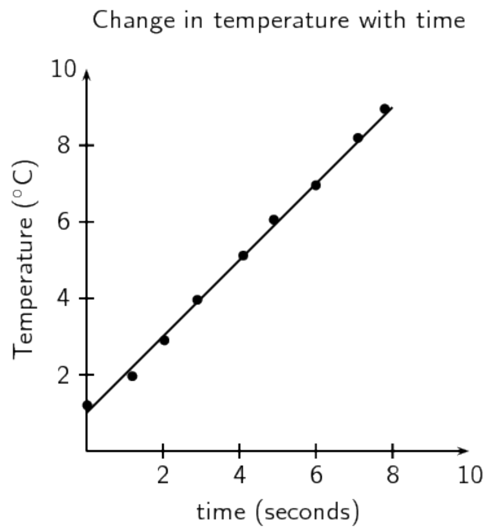


Figure 11: A straight line graph of the change in temperature with time.

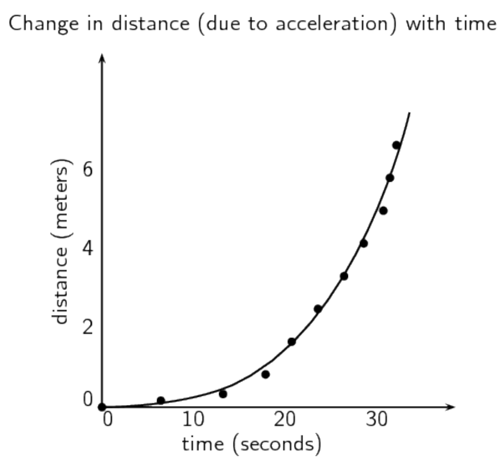


Figure 12: A graph with an exponential best fit line.

Remember that without units much of our work as scientists would be meaningless. We need to express our thoughts clearly and units give meaning to the numbers we measure and calculate. Depending on which units we use, the numbers are different. For example, if you have 12 water, it means nothing. You could have 12 ml of water, 12 litres of water, or even 12 bottles of water. Units are an essential part of the language we use. Units must be specified when expressing physical quantities.

3.2 Qualitative and quantitative analysis

3.2.1 Qualitative analysis

In **qualit**ative research you look at the quality of a substance. At how it looks compared to other cases. You do an in-depth analysis of a specific case, and then make an informed decision about similar cases.

For example, a qualitative study of the study habits of university students could include only a few people, or over twenty. Each person would be asked in-depth questions about how they study, and what works for them, and a general, informed assertion can then be made about these study habits.

3.2.2 Quantitative analysis

In **quant**itative research you look at specific numbers. You study a large group (data sample) and do statistical analyses of the group, with experimental controls, manipulation of variables, and the modelling and analysis of your data.

For example, a quantitative study of those same study habits of university students would include a large number of people, for statistical relevance. The questions asked would include raw data of actual studying hours, and the most productive study times. These data points would then be analysed using graphical models.

3.3 Designing a model

Sometimes a system is too large to be studied, or too difficult to recreate experimentally. In these cases it is possible to design a model based on a smaller system, that fits the data observed for the larger system. Here are some key points to remember when designing a model:

- A model is a testable idea that describes a large system that is not easily testable.
- The model should explain as many observations of the large system as possible, and yet be relatively simple.

An example of a model was the spherical model of the Earth, rather than a flat one.

- Many educated people of the day (in the late 1400s) knew that the Earth could not be flat due to observations that did not fit. A spherical Earth model was proposed, which was testable on a small scale.
- The model explained many previously unexplained phenomenon (such as that ships appeared to sink over the horizon, regardless of the direction of travel).
- The model was further verified by the shape of the Earth's shadow on the moon during lunar eclipses.

GENERAL EXPERIMENT

Boiling points and rate of evaporation: Part 2

Results

Now that you remember how to plot graphs, go back to the data you obtained during the previous experiment.

- On the same set of axes, plot a graph of the volume (ml) versus the time (min) for each substance.

Analysis of results or discussion

- Analyse the results plotted on the graphs and the table.
- Which substance has the fastest decrease in volume? Which has the slowest decrease?
- Discuss if there are any relationships between your independent (time) and dependent (volume) variables (what type of graph did you plot?).
- It is important to look for patterns/trends in your graphs or tables and describe these clearly in words.
- Compare the different graphs and the different rates of evaporation to the boiling points of the substances.

Evaluation of results

- This is where you answer the question *Is the rate of evaporation of a substance related to its boiling point?*
- You need to carefully consider the results:
  - Were there any unusual results? If so then these should be discussed and possible reasons given for them.
  - Discuss how you ensured the validity and reliability of the investigation. Was it a fair test (validity) and if the experiment were to be repeated would the results obtained be similar (reliability)? The best way to ensure reliability is to repeat the experiment several times and obtain an average.
  - Discuss any experimental errors that may have occurred during the experiment. These can include errors in the methods and apparatus. Make suggestions on what could be done differently next time.
  - Did this experiment yield qualitative or quantitative results?

3.4 Conclusions based on scientific evidence

GENERAL EXPERIMENT (continued)

Boiling points and rate of evaporation: Part 3

Conclusion

You have your results, and the analysis of your results. Now you need to look back at your hypothesis.

The conclusion needs to link the results to the aim and hypothesis. In a short paragraph, write down if what was observed supports or reject the hypothesis. If your original hypothesis does not match up with the final results of your experiment, do not change the hypothesis. Instead, try to explain what might have been wrong with your original hypothesis. What information did you not have originally that caused you to be wrong in your prediction.

ACTIVITY

Conclusions and bias

Read the following extract on bias taken from radiology.rsna.org $(01/09/13)$, and answer the questions that follow:

EXTRACT

Bias is a form of systematic error that can affect scientific investigations and distort the measurement process. A biased study loses validity in relation to the degree of the bias. While some study designs are more prone to bias, its presence is universal. It is difficult or even impossible to completely eliminate bias. In the process of attempting to do so, new bias may be introduced or a study may be rendered less generalizable. Therefore, the goals are to minimize bias and for both investigators and readers to comprehend its residual effects, limiting misinterpretation and misuse of data.

- In the light of the above quotation, why is it important for you to clearly state all your experimental parameters?
- Why is it important never to try and make the data fit your hypothesis?
- Look again at the conclusions you drew during your experiment.
  - Are they biased?
  - Did you make any assumptions based on preconceived ideas?
  - Is the data presented in a clear way that does not force a reader to agree with your conclusions?

ACTIVITY (continued)

Different, but acceptable explanations for the same set of experimental data.

To prevent bias, it is important to be able to look at the same information in different ways, to make sure your conclusion is the most logical one.

Divide into groups of three or four and compare the conclusions you drew from the boiling points and rate of evaporation experiment, and answer the questions that follow:

- Did anyone in the group draw a different conclusion from the one you drew? If yes, discuss the merits and short-falls of the different conclusions.
- Did your conclusion match what you were expecting to find from the hypothesis?
- Can you think of any other explanation that would explain your data?

Methods of knowing used by non-scientists.

Research one of the following topics and report your findings to the class in a five minute oral presentation:

- Traditional medicines.
- Navigation and knowledge of the seasons, from the stars.

4 LABORATORY SAFETY PROCEDURES

Laboratories have rules that are enforced as safety precautions. These rules are:

- Before doing any scientific experiment make sure that you know where the fire extinguishers are in your laboratory and there should also be a bucket of sand to extinguish fires.
- You are responsible for your own safety as well as the safety of others in the laboratory. Never perform experiments alone.
- Ensure that you are dressed appropriately whenever you are near chemicals:
  - hair tied back
  - no loose or flammable clothing
  - closed shoes
  - gloves
  - safety glasses
- Do not eat or drink in the laboratory. Do not use laboratory glassware to eat or drink from.
- Always behave responsibly in the laboratory. Do not run around or play practical jokes. Always check the safety data of any chemicals you are going to use. Never smell, taste or touch chemicals unless instructed to do so. Do not take chemicals from the laboratory.
- Only perform the experiments that your teacher instructs you to. Never mix chemicals for fun. Follow the given instructions exactly. Do not mix up steps or try things in a different order.
- Care needs to be taken when pouring liquids or powders from one container to another. When spillages occur you need to call the teacher immediately to assist in cleaning up the spillage.
- Care needs to be taken when using strong acids and bases. A good safety precaution is to have a solution of sodium bicarbonate in the vicinity to neutralise any spills as quickly as possible. If you spill on yourself wash the area with lots of water and seek medical attention. Never add water to acid. Always add the acid to water.
- When working with chemicals and gases that are hazardous, a fume cupboard should be used. Always work in a well ventilated area.
- When you are smelling chemicals, place the container on a laboratory bench and use your hand to gently waft (fan) the vapours towards you.
- Be alert and careful when handling chemicals, hot glassware, etc. Never heat thick glassware as it will break. (i.e. do not heat measuring cylinders).

- When lighting a Bunsen burner the correct procedure needs to be followed: securely connect the rubber tubing to the gas pipe, have your matches ready, turn on the gas, then light a match and the Bunsen burner. Do not leave Bunsen burners and flames unattended.
- When heating substances in a test tube do not overheat the solution. Remember to face the mouth of the test tube away from you and members of your group when heating a test tube.
- Always check with your teacher how to dispose of waste. Chemicals should not be disposed of down the sink.
- Ensure all Bunsen burners are turned off at the end of the practical and all chemical containers are sealed.

4.1 Hazard data

Before starting any experiment, research the chemicals and materials you will be using in that experiment. Laboratory chemicals can be dangerous, and you should study the safety data sheets before working with a chemical. The data sheets can be found at **http://www.msds.com/**.

Before working with a chemical, you should also make sure that you know how to, and have the facilities available to, dispose of those chemicals correctly and safely. Many chemicals cannot simply be washed down the sink. If you follow these few simple guidelines you can safely carry out experiments in the laboratory without endangering yourself or others around you.

5 EXERCISES

5.1 Exercise 1

1. Are the following statements true or false:

    1.1 Results are not made to fit the hypotheses.

    1.2 A scientific theory is not a theory that has been tested

2. Who is known for the earliest development of the theory of gravity?

3. What planet did Johann Gottfried Galle discover?

4. How many rules of thermodynamics are there?

5. In what year did the development of the thermodynamic rules start?

5.2 Exercise 2

1. In what order should you communicate your findings to the public? (rearrange the items given below)
   (i) discussion
   (ii) aim
   (iii) apparatus
   (iv) conclusion
   (v) method
   (vi) results

2. Is the following statement true or false: In science, we never prove a hypothesis through a single experiment.

3. Name the three types of variables

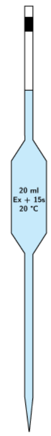
4. Study the figure below:

   What do the short lines represent?

5. Is the following statement true or false:
   Your thermometer does not need to be upright for accurate results

6. Name the following apparatus :



5.3 Exercise 3

1. Are the following statements concerning the features of graphs true or false.
    1.1 The independent variable is generally plotted along the x-axis.
    1.2 Use exponential graphs when the relationship between the dependent and independent variables is continuous.
    1.3 Always start a graph at the origin.
2. Is the following statement concerning qualitative and quantitative analysis true or false.
    2.1 In qualitative research you look at the quality of a substance.
3. Is the following statement concerning designing a model true or false.
    3.1 A model is a testable idea that describes a large system that is not easily testable.

5.4 Exercise 4

1. Are the following laboratory safety rules true or false.
    1.1 Always perform experiments alone.
    1.2 While performing experiments keep your hair loose and untied.
    1.3 Always wear closed shoes.
    1.4 Never mix chemicals for fun.
    1.5 Chemicals should be disposed of down the sink.
    1.6 Care needs to be taken when using strong acids and bases.

6 ANSWERS TO EXERCISES

6.1 Exercise 1

1.1 True, the results are not made to fit the hypotheses.

1.2 False, a scientific theory is one that has been tested and proven through repeated experiment and data.

2.2 Galileo Galilei. Galileo Galilei is credited with some of the earliest work on the theory of gravity.

2.3 Neptune, Newton's theory was used by John Couch Adams and Urbain Le Verrier to predict the planet Neptune in the solar system and this prediction was proved experimentally when Neptune was discovered by Johann Gottfried Galle.

2.4 There are three rules of thermodynamics.

2.5 The basis for these three rules started as far back as 1650 with Otto von Guericke.

6.2 Exercise 2

1. (ii) aim
   (iii) apparatus
   (v) method
   (vi) results
   (i) discussion
   (iv) conclusion
2. True, in science we never 'prove' a hypothesis through a single experiment because there is a chance that you made an error somewhere along the way.
3. Independent, dependent, and controlled variables
4. 1mm
5. False, make sure your thermometer is upright whenever you use it in an experiment, to avoid incorrect results.
6. Pipette

6.3 Exercise 3

1.1 True, The independent variable is generally plotted along the x-axis, while the dependent variable is generally plotted along the y-axis.

1.2 False, Use line graphs when the relationship between the dependent and independent variables is continuous.

1.3 False, Do not start the graph at the origin unless there is a data point for $(0{,}0)$, or if the best fit line runs through the origin.

2.1 True, In qualitative research you look at the quality of a substance. At how it looks compared to other cases. You do an in-depth analysis of a specific case, and then make an informed decision about similar cases.

3.1 True, a model is a testable idea that describes a large system that is not easily testable.

6.4 Exercise 4

1.1 False, Never perform experiments alone.

1.2 False, Ensure that you are dressed appropriately whenever you are near chemicals: hair tied back

1.3 True

1.4 True

1.5 False, Chemicals should not be disposed of down the sink

1.6 True.