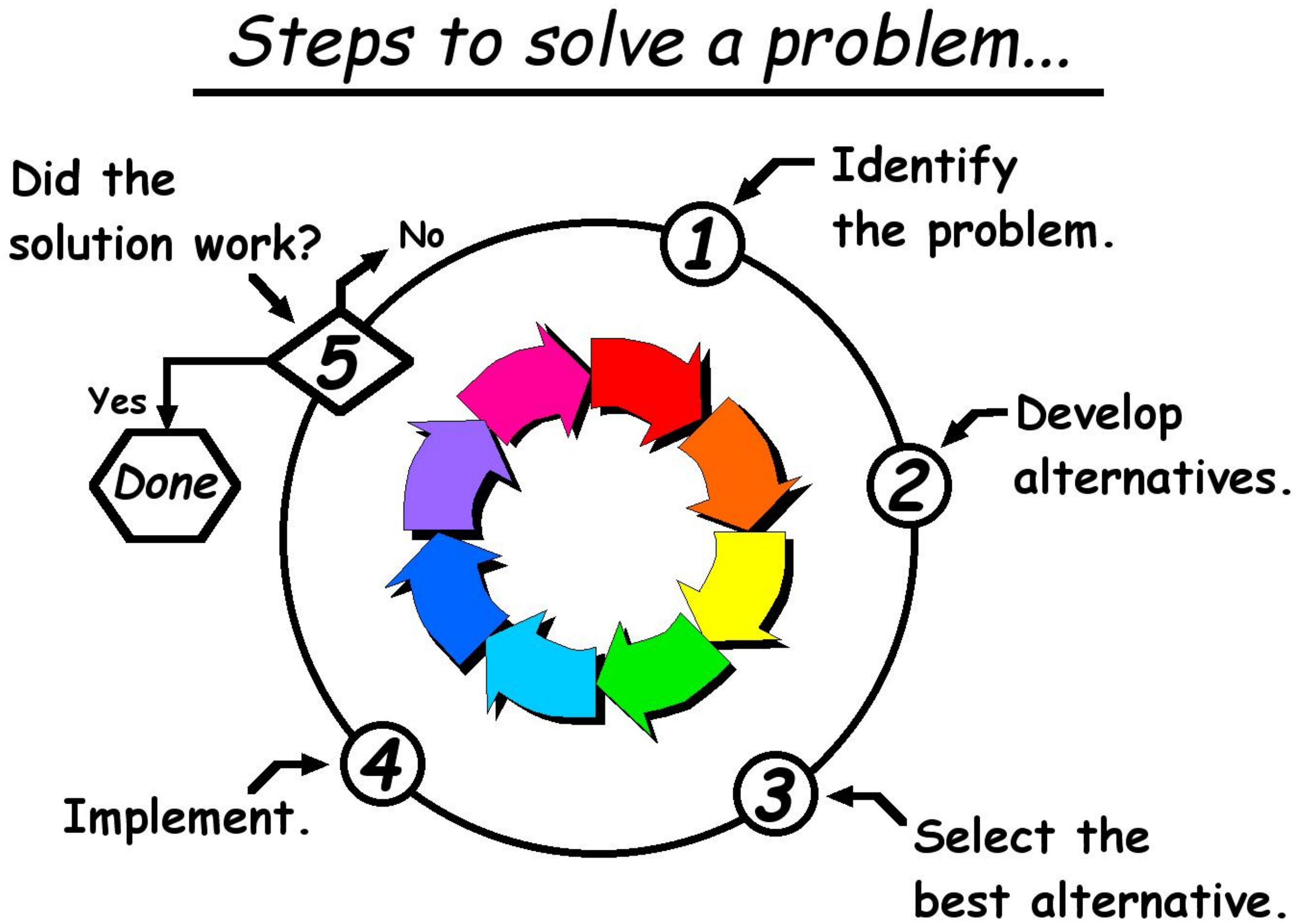
Problem Solving Skills

Stages in the problem solving process	
Identify the problem	Identify a defined problem
Define the problem	Represent the problem in your own words, defining the key words, terms and concepts. You should ask yourselves questions such as: • What do I know already about this problem or question? • What do I need to know to effectively address this problem or question? • What resources can I access to determine a proposed solution or hypothesis? In this stage, a very focused problem statement is needed, though that statement will go through a series of changes as new information is accessed and processed.
Collect, evaluate and organise information about the problem	Determine what information will be relevant, useful and absolutely essential for solving the problem; retrieve information from print, web and other sources; classify and categorise relevant information.
Create or select a strategy to resolve the problem	Collect examples of similar problems and the strategies used to solve them.
Allocate resources to solve the problem	Develop timelines, action plans, progress reports and role allocations to ensure the problem is satisfactorily resolved.
Monitor the problem solving process	Submit regular progress reports or updates to ensure deadlines are met; require submission of reflective documents on process issues as part of their assessment.
Evaluate the final solution	Evaluate their final solution to the problem from multiple perspectives (e.g., an accountant; a manager; a researcher; an end-user; an advertising agent) to test its validity in a range of contexts.

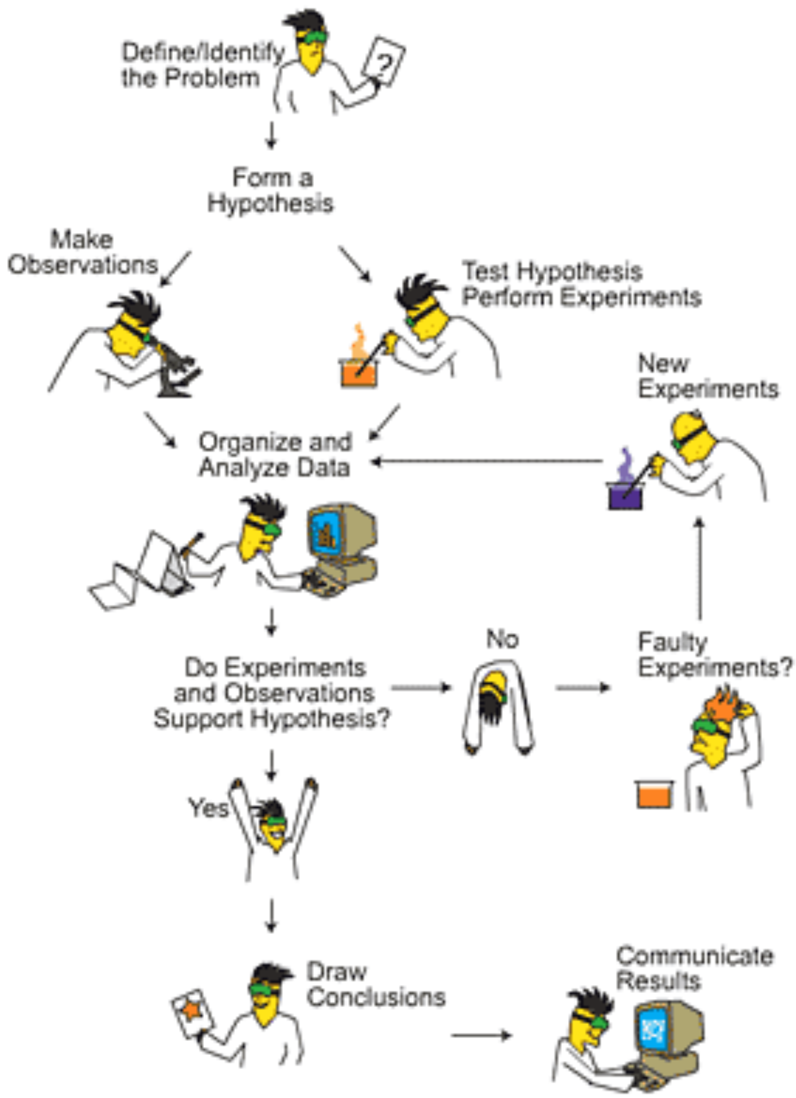


The Scientific Method

A general version of how it works

Define/Identify the Problem

1. Form a Hypothesis
2. Make Observations or Test Hypothesis and Perform Experiments
3. Organize and Analyse Data
4. Do Experiments
5. Record Observations, Do they Support the Hypothesis?
    - If No, Perform New Experiments and Repeat Step 4
6. Draw Conclusions based on data
7. Communicate Results



Science Experiments: The Scientific Method

Writing up an Experiment

<table>
<tr><td>Aim</td><td colspan="3">To …investigate, determine, find, explore, relate, connect, link, etc.</td></tr>
<tr><td>Hypothesis</td><td colspan="3">An educated guess. Must be testable by experiment. Hypothesis does not have to be the correct answer.</td></tr>
<tr><td rowspan="4">Procedure (Method)</td><td rowspan="2">Variables

These are factors that can change in an experiment</td><td>Experimental
These are the variables being studied</td><td>Independent: The variable that is changed by the experimenter
Dependent: This variable changes because of changes in independent variable (what we measure)</td></tr>
<tr><td>Controlled</td><td>These are the variables that you are not investigating in this experiment. If you are not careful, these variables may interfere with your results and conclusions. Your results and conclusions may not be valid.</td></tr>
<tr><td>Accuracy</td><td colspan="2">Measuring instruments determine how accurate your results are. Instruments that are more sensitive (can read smaller differences between values) will give results that are more accurate. Using measuring instruments will be more accurate than not using measuring instruments.</td></tr>
<tr><td>Reliability</td><td colspan="2">Repetition or replication is almost always done in science experiments. This will ensure that your result is not a “fluke”, but happens almost every time the experiment is done.</td></tr>
<tr><td rowspan="2">Results</td><td>Tables</td><td colspan="2">Remember: Use a ruler
Draw a box around the outside
Headers contains quantities, eg time, length, mass, etc
Units in brackets, eg (sec), (cm), (kg), etc.</td></tr>
<tr><td>Graphs</td><td colspan="2">Use pencil only
Axes: must have a linear scale
Quantities
Units in brackets.
Points marked as very small crosses.
Line may be point-to-point or may be line of best fit.
Ruler
Interpolation: reading between measured data. Usually quite safe.
Extrapolation: reading beyond measured data. Not always safe.</td></tr>
<tr><td>Conclusion</td><td colspan="3">What do your results mean in terms of your aim and your hypothesis?
Validity: Have the variables been controlled?</td></tr>
<tr><td>Discussion</td><td colspan="3">Improvements: How could the experiment be made more accurate? How could it be made more reliable? Are the results and conclusions valid? Are some other conclusions possible from your results?
Generalising: What do your conclusions mean across the area of knowledge you have investigated? Are there implications for other experiments? Can you suggest further investigations that could be done?</td></tr>
</table>

Example

Pendulum Experiment

Aim: To discover the effect of changing the length of a pendulum on its period of swing.

Hypothesis: Changing the length has no effect on the period of a pendulum.

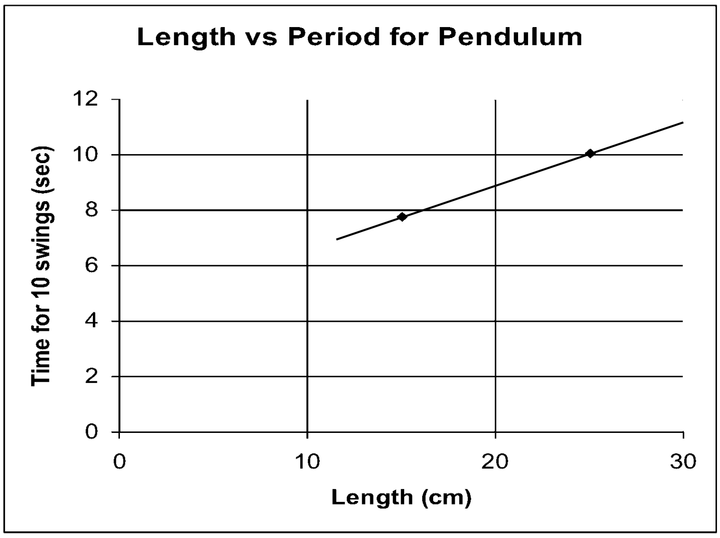
Procedure:

1. A 50 gram mass is tied to the end of a length of thin thread.
2. The other end of the thread is tied to a clamp attached to a retort stand.
3. The distance from the clamp to the end of the mass is adjusted to 25 cm using a ruler marked in millimetres.
4. The hanging mass is pulled to one side to a distance of 5 cm.
5. The hanging mass is released. The time for 10 complete swings of the pendulum is measured with a stopwatch.
6. Step 5 is repeated to check the reliability of the procedure.
7. The distance from the clamp to the end of the mass is adjusted to 15 cm.
8. The hanging mass pulled to one side to a distance of 5 cm and released.
9. The time for 10 complete swings is measured, and repeated.

*In this procedure, the experimenter adjusted the length of the pendulum, so this is the **independent** variable. The time taken for the pendulum to swing is then the **dependent** variable.*

Results:

Length of pendulum (cm)	Time for 10 swings (sec)		
	First trial	Second trial	Average
25 cm	10.0	10.1	10.05
15 cm	7.7	7.8	7.75



*Note that the independent variable, **length**, goes on the*
***X axis** of the graph and the dependent variable goes on*

We don't have enough information to draw the line any further. Do not be tempted to draw the line through (0, 0) unless you have measured those

Conclusion: Changing the length of a pendulum does change the time taken for it to swing through 10 periods. The longer pendulum takes a longer time to swing. The hypothesis is not supported by the results.

Discussion

*The time of swing could not have been changed by anything else, because **only** the length of the pendulum was changed. The mass of the pendulum, the width of swing or the location of the experiment were not changed. The conclusion is **valid**. Each of the tests were repeated twice. The results of the two tests per length were very similar in each case. The results can be said to be reasonably **reliable**, however a larger sample of test results would improve the reliability of the results and hence the conclusion. The measurements were done with quality instruments, a stopwatch and a ruler marked in millimetres and the mass can be assumed to be accurate (fixed mass), so the results can be said to be **accurate**.*

The role of observation in science

Image: Hand sorting earthworms

Observation is something we often do instinctively. Observation helps us decide whether it's safe to cross the road and helps to determine if cupcakes are ready to come out of the oven. Observation is more than simply noticing something. It involves perception (becoming aware of something by means of the senses) and the recognition of the subject's importance or significance. Standing on a roadside, our eyes tell us cars are quickly approaching. Prior knowledge warns us that stepping in front of a car is dangerous, so we wait until the road is clear.

Observation is essential in science. Scientists use observation to collect and record data, which enables them to construct and then test hypotheses and theories. Scientists observe in many ways – with their own senses or with tools such as microscopes, scanners or transmitters to extend their vision or hearing. These tools allow for more precise and accurate observations. Scientists also use equipment to measure things like radiation or pH – phenomena not directly observable.

Observing earthworms

Humans have been observing earthworms and their activities for a very long time. The Ancient Greek philosopher Aristotle referred to earthworms as "the intestines of the earth". Charles Darwin is credited with inspiring popular and scientific interest in earthworms with his book *The Formation of Vegetable Mould through the Action of Worms, with Observations on their Habits*. Darwin kept pots of soil in his study so he could observe earthworms. He tested their sensitivity to light and heat, observed their food preferences and even set up challenges to test their intelligence!

Fast forward 50 years and observations of a more practical nature were taking place in New Zealand. A Raetihi farmer noticed that parts of his farm were more productive than others. He thought this was due to lumbricid earthworms living in some of his paddocks but absent in others, so he experimented by distributing earthworms around his farm. A few years later, scientists backed up the farmer's observations and quantified the positive effects earthworms have on pastoral productivity.

Research into earthworm activity continues today. It is well known that earthworm burrows increase water infiltration and soil aeration and that earthworms have a major impact on nutrient cycling. Some questions remain though. Which species are present and where? How much do they eat? How are they affected by farm management practices?

Observation techniques

To answer such questions, soil scientists Dr Nicole Schon from AgResearch and Dr Trish Fraser from Plant & Food Research use a number of techniques. To identify and quantify which species of earthworms live in an area, the most reliable method is hand sorting. This involves digging a cube of soil, sifting through it and counting the earthworms. The advantages of this method are its reliability and simplicity. The disadvantages are that it is time consuming and laborious and it destroys the burrows.

Image: Soil core inside a CAT scanner

Earthworm burrows are difficult to observe but Trish has found a novel way to make non-destructive measurements of the burrows – computed axial tomography (CAT). CAT scans X-ray internal density. They are often used for medical reasons. However, Trish has scanned soil cores both with and without earthworms to observe physical changes in the soil structure. The burrows stay intact so Trish can observe how they develop and change with time. The downside is cost. CAT scans are expensive for humans and earthworms alike!

Scientists aren't the only ones observing earthworms. Farmers and others use earthworms as a simple way to monitor soil health. Nicole has developed an identification guide that offers advice on when and how to sample for earthworms. Photos help the user to identify the earthworms from the soil samples. Different species provide different soil services (like organic matter incorporation or creating soil pores) so it is useful for farmers to know how many and what types of earthworms live in their soil.

For many students, one earthworm probably resembles the next as it struggles across the footpath on a rainy morning. Hopefully, this perception will change as students learn about how useful these creatures are to the soil ecosystem and spend some time observing their physical characteristics and movement!

NATURE OF SCIENCE

Observations may be the catalyst to scientific investigations. The Raetihi farmer's observation of his paddocks' differing productivity levels led him to experiment by distributing earthworms around his farm.

http://sciencelearn.org.nz/Science-Stories/Earthworms/The-role-of-observation-in-science

Selecting Equipment

Qualitative observations require the use of the senses to gather data in order to interpret what is happening in our surroundings and then make conclusions based on these interpretations. Quantitative observations gather data by using measurements. From these measurements we can interpret the data and draw conclusions. How exactly do scientists gather all of this numerical data? What kind of equipment is necessary and for what purposes? How accurate is it? Let's take a look, first at some of the typical equipment used in chemistry and then at the skills necessary to determine accuracy and precision. Let's explore the quantitative side of chemistry.

Equipment Determines the Unit of the Measurement

Think of the last laboratory experiment that you did. What kind of equipment did you use? If you were measuring out a volume of a liquid, did you use a beaker or a graduated cylinder?

Beakers used in experiments.

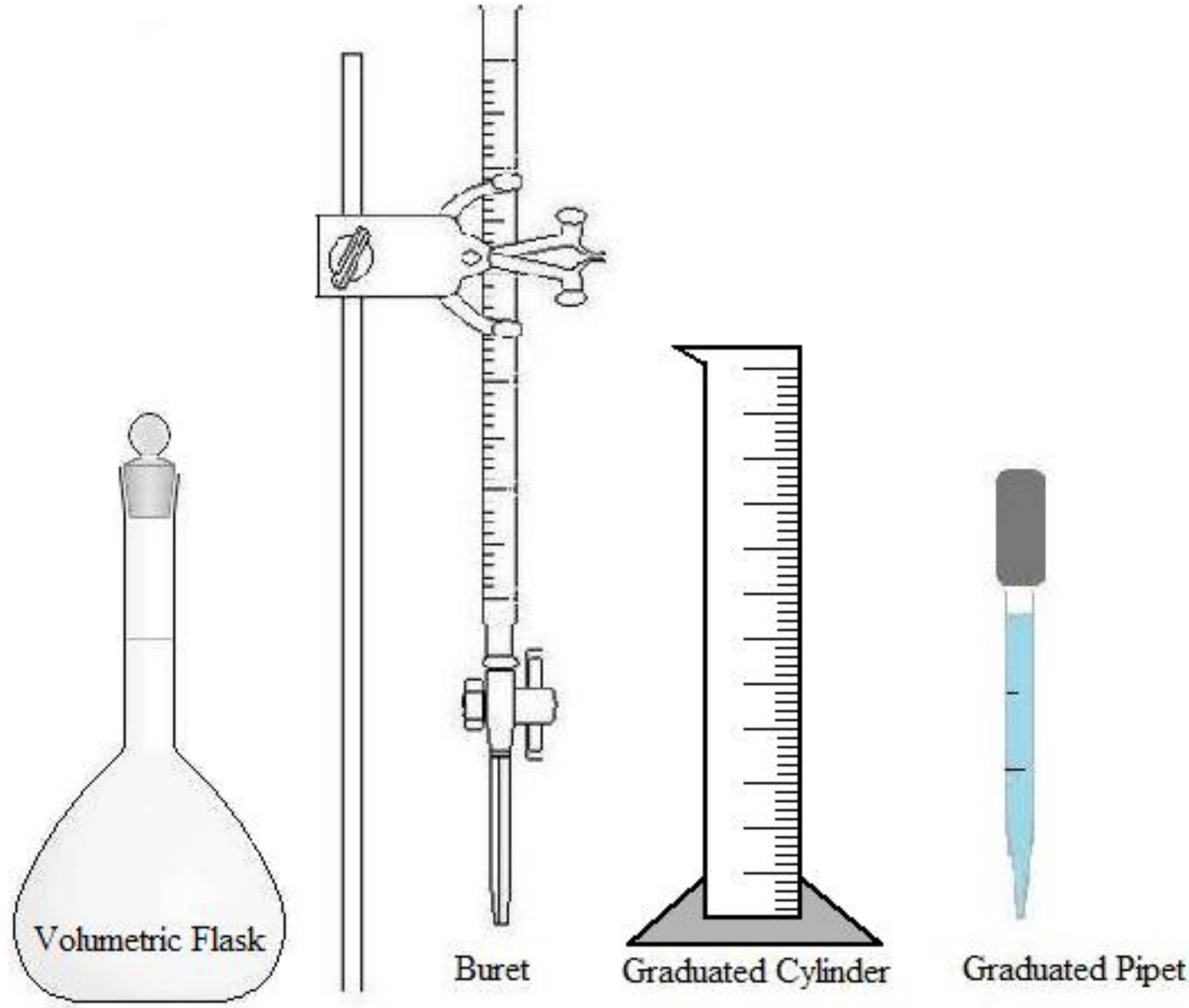
100 mL graduated cylinder.

Look at the two figures above; if you were required to measure out 65 mL, what instrument would you most likely want to use? The graduated cylinder has graduations every 10 mL and then further graduations every 5 mL. The beakers could have graduations every 10 mL, 50 mL, or 100 mL depending on which type you use. It would be easier to measure out the volume in a graduated cylinder. What if, in this same lab, you needed to mass out 3.25 g of sodium chloride, NaCl. Look at the two figures below and determine which piece of equipment you would use.


A pan balance.

A digital balance.

The pan balance measures only to ± 0.1 g. Therefore, you would have to mass out 3.3 g of NaCl rather than 3.25 g. The digital balance can measure to ± 0.01 g. With this instrument you could measure exactly what you need, depending on your skill of course!
The equipment you choose also determines the units in your measurement and vice versa. For example, if you are given graduated cylinders, beakers, pipettes, burettes, flasks, or bottles, you are being asked to measure volume. Volume measurements in the International System of Units use the metric system rather than the imperial system in order to standardize these measurements around the globe. Thus, for volume measurements, we use liters (L) for large volumes and milliliters (mL) for smaller volumes measured in the lab. Look at the figure below and determine what volumes are present in each piece of equipment.



Volume equipment pieces.

The contrary is also true. What if you were to measure out 5 g of a solid, or 3 cm of wire, or the temperature of a solution; would any of the objects in the figure above be helpful? Why not? These objects are not helpful because these units of measurement are not volumes and all of these pieces of equipment measure volume. For the measurements you need to take, you would need different pieces of equipment. Look at the figure below and match the three required measurements with the pieces of equipment shown.

a) 5 g of a solid
b) 3 cm of wire
c) temperature of a solution

Examples of measuring devices.

Equipment Determines the Significant Figures

In the previous section, we looked at a lot of equipment that is used for measuring specific units. The graduated cylinder that measures volume, the balance that measures mass, and the thermometer that measures temperature are a few that we looked at before. We also saw that of two types of balances, one type of balance can more precisely measure mass than the other. The difference between these two balances has to do with the number of significant digits that the balances are able to measure. Remember the pan balance could measure to ± 0.1 g and the digital balance can measure to ± 0.01 g.

Before going any further, what do we recall about significant digits? A measurement can only be as accurate as the instrument that produced it. A scientist must be able to express the accuracy of a number, not just its numerical value. The instruments that we choose for the laboratory experiments depend on the required amount of accuracy. For example, if you were to make a cup of hot chocolate at home using powdered cocoa, you would probably use a measuring spoon or a teaspoon. Compare this to the requirement of massing out 4.025 g of sodium bicarbonate for a reaction sequence you are doing in the lab. Would the teaspoon do? Probably not! You would need to have what is known as an analytical balance that measures to ± 0.001 g.

Accuracy and Precision

Accuracy and precision are two words that we hear a lot in science, in math, and in other everyday events. They are also, surprisingly, two words that are often misused. How often have you heard these terms? For example, you often hear car advertisements that talk about their precision driving ability. But what do these two words mean. **Accuracy** is how close a number is to the actual or predicted value. If the weatherperson predicts that the temperature on July 1st will be 30 °C and it is actually 29 °C, she is likely to be considered pretty accurate for that day.

Once you have gone into the lab and made measurements, whether they are mass, volume, or length, how do you know if they are correct? Accuracy is the difference between a measured value and the accepted - or what we call the correct - value for that quantity. To improve accuracy, scientists will repeat the measurement as many times as is possible. **Precision** is a measure of how close all of these measurements are to each other. Therefore, measurements can have precision but not very close accuracy. An example of accuracy of measurements is having the following data: 26 mL, 26.1 mL, and 25.9 mL when the accepted value is 26.0 mL. This data also shows precision. However, if the data had been 25.2 mL, 25.0 mL, and 25.2 mL, they would show precision without accuracy.

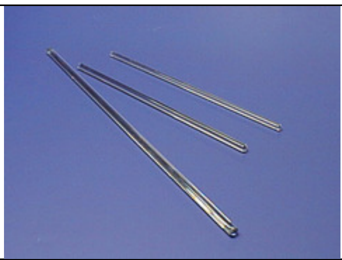
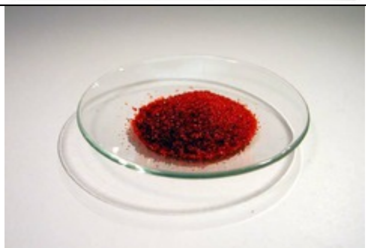
Sample Question
Jack collected the following volumes when doing a titration experiment: 34.25 mL, 34.30 mL, 34.60 mL, 34.00 mL, and 34.50 mL. The actual volume for the titration required to neutralize the acid was 34.50 mL. Would you say that Jack's data was accurate? Precise? Both accurate and precise? Neither accurate nor precise? Explain.
Solution:
All of Jack's data would be accurate because they are close to the true value of 34.50 mL. The data would also be precise having only 2% variance between the highest number and the lowest number.

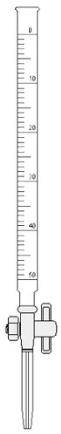
Extracted from

http://en.wikibooks.org/wiki/High_School_Chemistry/Chemistry_in_the_Laboratory

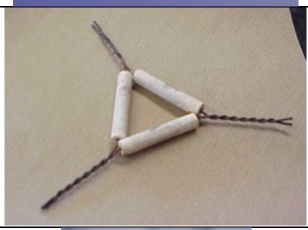
Equipment Examples and Uses

	goggles	protects eyes from chemical splashes
	Bunsen burner	used to heat substances
	graduated cylinder	accurately measures liquid volumes

	spot plate	a flat plate with multiple "wells" used as small test tubes
	pipet bulb	used to pull liquid up into a pipet
	stirring rod	used for stirring
	evaporating dish	liquids are heated over a flame so that they evaporate, leaving a solid residue
	tongs	to hold hot objects
	forceps	used to pick up or hold small items
	watch glass	to hold solids while being weighed, or as a cover for a beaker
	beaker	used to hold liquids

	thermometer	measures temperature (science uses degrees in Celsius)
	crucible and cover	used to hold small amounts of chemicals during heating at high temperatures
	test tube clamp	clamp used to hold hot test-tube
	buret	dispensing and transferring known volumes of fluids
	Electronic balance	an instrument for determining weight
	dropper pipet or disposable pipet	for drawing in a liquid and expelling it in drops
	volumetric flask	for making up solutions to a known volume

	funnel	for pouring liquid or other substance through a small opening
	Mortar and Pestle	used to grind up materials
	volumetric pipet	measures small amounts of liquids accurately
	rubber stopper	used to cover ends of test tubes and flasks
	spatula	small scoop used to transfer powder and crystal chemicals
	wire gauze	used to support a container (such as a beaker or flask) during heating
	test tube rack	holds 5-6 test-tubes in a row
	wash bottle	used to rinse various pieces of laboratory glassware

	Retort Stand	holds funnels, wire gauze above table
	Erlenmeyer flask / Conical Flask	used to hold liquids, has narrow neck to prevent splashes
	ring clamp	used with ring stand to hold a glass container
	clay triangle	used to hold a crucible while the crucible is heated
	test tube	open tube used to hold liquids
	filter paper	special paper used to separate solids from liquids
	fume hood/gas cabinet	used to prevent a person from exposure to hazardous fumes from chemicals
	hot plate / stir plate	used to heat and stir substances