HSC CHEMISTRY

Syllabus Notes 2007

Andrew Harvey

1st Edition

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If you have any queries on this document, I can be contacted at andrew.harvey4@gmail.com
I would appreciate and welcome your comments/corrections/suggestions, please send them to my e-mail.

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Some of the sample problems are past HSC exam questions. Where this is the case the source has been acknowledged. Any solutions do not in any way reflect the Board of Studies NSW view, they are the view of the author.

CONTENTS

PREFACE

Preamble

These syllabus notes were written to help students to understand and succeed in Chemistry at High School. They are based on the NSW Board of Studies HSC Chemistry Syllabus (Revised 2003). These notes are not a text book and as such I have tried to only include the information that is needed as the syllabus stipulates. I have taken the approach to cover each dot point on its own rather than cover topics like text books do. I have done this to make it easier to read, understand and memorise.

I have included an extensive, but still quite short coverage of syllabus topic 9.1 skills. This is meant to be integrated with the content however I decided it was easier to cover it separately. You should note that it is very rarely examined directly, except for basic graphing skills, and sometimes reliability, validity and accuracy. You should spend most of your time covering the content as you know there will a lot of that in the exam.

These notes have been proof read by a Chemistry teacher and the information has been collected from many reliable sources and cross referenced (see the references section). However I will not be held liable for any error in these notes. My references include class lectures, HSC & university level text books, summary notes, web sites, conference proceedings, journal articles, past HSC exams, past HSC notes from the Marking Centre and many other sources. If you find any aspects which are incorrect or could be worded better please let me know and I'll do my best to fix it.

For the Student

To succeed in the HSC examination you need to be able to do three main things. Firstly, you need to *memorise* the content. Secondly, you need to *understand the concepts*. Questions do not always ask you to recall a memorised slab of information, they sometimes require you to think critically and solve problems. To be able to do this you need to have a clear and deep understanding of the chemistry. Thirdly and the most important of all, is that you need to be able to *communicate your ideas*. There is no use in knowing the answer to the question if you cannot communicate this through writing or diagrams to the marker.

So I guess the key to success in HSC Chemistry is to be good at those three things. These notes aim to help you on the first two points and my sister publication *HSC Chemistry Past Paper Solutions* aims to help you with the third and second aspects.

Different people study in different ways, you should do what works for you, however what I found most effective in studying chemistry was to firstly turn up to the lesson and try to understand what the teacher is saying. Don't try to memorise everything, but rather try to understand what was being said. Like everyone else, I understood very little when it was first explained. That is why you need to do more.

Within a week of the lesson you should go though the content of the lesson in various text books and study guides such as these syllabus notes. In this stage you should begin to understand much of the content. You teacher is there to help you and many times they will help you. Consult your teacher and seek clarification of any aspects that you do not understand. Once you have finished a topic you should find some past paper questions and tackle them. But remember that this method worked for me. You should do what you find works for you.

When you refer to text books, you should not just use one book. You should get your hands on all of the main HSC Chemistry text books available and read and try to understand them. Don't try to learn it all at once. It may help to wait until you have covered the material in class before you begin to study it at home, but either way you should read these HSC texts. Also relying on one text or one source is a bad idea. One text may explain it in a different way, or present ideas that the other text did not. Or sometimes one source may be wrong. You should use as many as you can. But this is not limited to HSC texts. The HSC texts are pretty much based on first and second year university level text books, so you should get your hands on the popular university level texts. I used only one, but I found myself referring to it frequently. Often it has a much clearer and accurate explanation that helps me understand the chemistry. There are also a wide range of journal articles, periodicals, conference proceedings, web sites, and other material that is often quite useful. You should refer to these.

As a final note I would appreciate it if you could give me feedback about these notes. The feedback would help me in future editions also I would like to know how many people have read these notes.

About the Author

Greetings fellow Chemistry students! I am just an ordinary chemistry student who found the course extremely difficult. It is not easy and I found that there was a lack of resources out there, so I decided to publish my Syllabus Notes in a bid to help out others.

I completed my HSC in 2007 at Blakehurst High School, a non-selective government school. In my school assessment chemistry I was ranked 7/36 in my school and attained a trial mark of 77%. In the external HSC examination I attained a band 5 with a mark of 84. However please be aware that the exam examines a certain set of skills. Different skills are used in writing a science text book. Just because the author attained a band 5 does not mean they are incompetent at writing a text book.

Syllabus Extracts

Context
Contexts are frameworks devised to assist students to make meaning of the Prescribed Focus Areas and Domain. Contexts are culturally bound and therefore communicate meanings that are culturally shaped or defined. Contexts draw on the framework of society in all aspects of everyday life. The contexts for each module encourage students to recognise and use their current understanding to further develop and apply more specialised scientific understanding and knowledge.

Prescribed Focus Areas
The Prescribed Focus Areas are different curriculum emphases or purposes designed to increase students’ understanding of chemistry as an ever-developing body of knowledge, the provisional nature of scientific explanations in chemistry, the complex relationship between evidence and ideas in chemistry and the impact of chemistry on society.

The following Prescribed Focus Areas are developed in this syllabus:

History of chemistry
Knowledge of the historical background of chemistry is important to adequately understand natural phenomena and explain the applications of those phenomena in current technologies. Students should develop knowledge of:

- the developmental nature of our understanding of energy, matter and their interrelationships
- the part that an understanding of energy, matter and their interrelationships plays in shaping society
- how our understanding of energy, matter and their interrelationships is influenced by society.

Nature and practice of chemistry
A study of chemistry should enable students to participate in scientific activities and develop knowledge of the practice of chemistry. Students should develop knowledge of the provisional nature of physical explanations and the complex relationship between:

- existing physical views and the evidence supporting these
- the process and methods of exploring, generating, testing and relating ideas
- the stimulation provided by technological advances and constraints imposed on understanding in chemistry by the limitations of current technology that necessitates the development of the required technology and technological advances.

Applications and uses of chemistry
Setting the study of chemistry into broader contexts allows students to deal with real problems and applications.
The study of chemistry should increase students’ knowledge of:

- the relevance, usefulness and applicability of laws and principles related to chemistry
- how increases in our understanding in chemistry have led to the development of useful technologies and systems
- the contributions chemistry has made to society, with particular emphasis on Australian achievements.

Implications of chemistry for society and the environment
Chemistry has an impact on our society and the environment, and students need to develop knowledge of the importance of positive values and practices in relation to these. The study of chemistry should enable students to develop:

- understanding about the impact and role of chemistry in society and the environment
- skills in decision-making about issues concerning chemistry, society and the environment.

Current issues, research and developments in chemistry
Issues and developments related to chemistry are more readily known and more information is available to students than ever before. The syllabus should develop students’ knowledge of:

- areas currently being researched in chemistry

- career opportunities in chemistry and related fields
- events reported in the media which require an understanding of some aspect of chemistry.

Domain
Knowledge and understanding
As one of the major disciplines of science, the Chemistry Stage 6 course presents a particular way of thinking about the world. It encourages students to use inference, deductive reasoning and creativity. It presumes that the interrelationships within and between matter and energy in the universe occur in consistent patterns that can be understood through careful, systematic study.

The course extends the study developed in the Science Stages 4–5 course, particularly in relation to students' knowledge and understanding of the law of conservation of energy, Newton's Laws, the wave model, particle theory of matter, atomic theory, types of energy, types of force, technology and resources.

This course will build upon this fundamental knowledge to increase students' conceptual understanding of systems involving energy, force and motion as well as interactions between these systems and the living and non-living world. The course will assume that students have an elementary knowledge and understanding of energy, motion, electricity and forces as developed in the Science Stages 4–5 course.

Skills
The Chemistry Stage 6 course involves the further development of the skills students have developed in the Science Stages 4–5 course through a range of practical experiences in both the Preliminary and HSC courses.

Practical experiences are an essential component of both the Preliminary and HSC courses. Students will complete **80 indicative hours of practical/field work across both the Preliminary and HSC courses** with no less than 35 indicative hours of practical experiences in the HSC course. Practical experiences have been designed to utilise and further develop students' expertise in each of the following skill areas:

- **planning investigations**

This involves increasing students' skills in planning and organising activities, effectively using time and resources, selecting appropriate techniques, materials, specimens and equipment to complete activities, establishing priorities between tasks and identifying ways of reducing risks when using laboratory and field equipment.

- **conducting investigations**

This involves increasing students' skills in locating and gathering information for a planned investigation. It includes increasing students' skills in performing first-hand investigations, gathering first-hand data and accessing and collecting information relevant to chemistry from secondary sources using a variety of technologies.

- **communicating information and understanding**

This involves increasing students' skills in processing and presenting information. It includes increasing students' skills in speaking, writing and using nonverbal communication, such as diagrams, graphs and symbols to convey physical information and understandings. Throughout the course, students become increasingly efficient and competent in the use of both technical terminology and the form and style required for written and oral communication in chemistry.

- **developing scientific thinking and problem-solving techniques**

This involves further increasing students' skills in clarifying issues and problems relevant to chemistry, framing a possible problem-solving process, developing creative solutions, anticipating issues that may arise, devising appropriate strategies to deal with those issues and working through the issues in a logical and coherent way.

- **working individually and in teams**

This involves further increasing students' skills in identifying a collective goal, defining and allocating roles and assuming an increasing variety of roles in working as an effective member of a team within the agreed time frame to achieve the goal. Throughout the course, students will be provided with further opportunities to improve their ability to communicate and relate effectively with each other in a team.

Values and attitudes
By reflecting about past, present and future involvement of chemistry with society, students are encouraged to develop positive values and informed critical attitudes. These include a responsible regard for both the living and non-living components of the environment, ethical behaviour, a desire for critical evaluation of the consequences of the applications of chemistry and recognising their responsibility to conserve, protect and maintain the quality of all environments for future generations.

Students are encouraged to develop attitudes on which scientific investigations depend such as curiosity, honesty, flexibility, persistence, critical thinking, willingness to suspend judgement, tolerance of uncertainty and an acceptance of the provisional status of scientific knowledge. Students need to balance these with commitment, tenacity, a willingness to take risks, make informed judgements and at times, inflexibility. As well as knowing something about chemistry, students also need to value and appreciate chemistry if they are to become scientifically literate persons.

9.1 CHEMISTRY SKILLS

Contextual Outline:

During the HSC course, it is expected that students will further develop skills in planning and conducting investigations, communicating information and understanding, scientific thinking and problem solving and working individually and in teams. Each module specifies content through which skill outcomes can be achieved. Teachers should develop activities based on that content to provide students with opportunities to develop the full range of skills.

X

H11. justifies the appropriateness of a particular investigation plan

11.1 identify data sources to:

a) analyse complex problems to determine appropriate ways in which each aspect may be researched

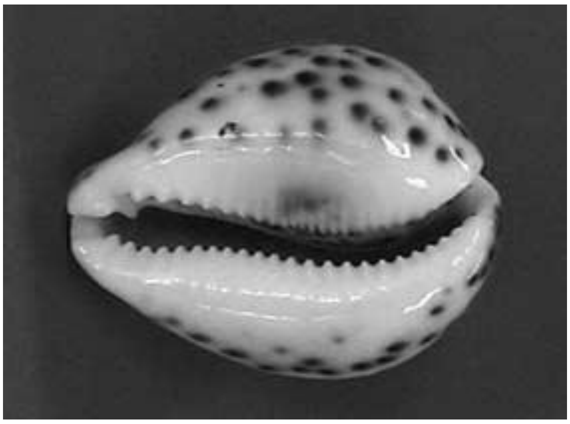
b) determine the type of data which needs to be collected and explain the qualitative or quantitative analysis that will be required for this data to be useful

The type of data collected can vary. The data may be numerical quantities such as the mass of an object, or it may be observations such as the colour of something or its smell.

Data can be analysed qualitatively or quantitatively. Qualitative analysis refers to analysing it in regards to its qualities. For example you may observe the colour of the emission spectra of an element. You are not performing any numerical calculations, therefore you are qualitatively analysing the data. Quantitative analysis refers to analysing it in regards to numerical calculations. You may do an experiment where you change length and measure time. From this data you collect you may apply some mathematical formula to come to some conclusion. As you have performed calculations on this data, you have quantitatively analysing the data. An example of an analysis of a shell is shown below.

Qualitative observations

- pink and cream with brown spots
- pointed at one end
- long serrated opening
- very shiny surface



Quantitative observations

- 6 cm long, 4 cm wide
- centre opening 0.5 cm wide
- mass of 46 g

Fig. (1)

Learning Materials Production (LMPC). (2001). *Making and recording observations.* Retrieved November 2007, from Hints for your research project: http://www.lmpc.edu.au/resources/Science/research_projects/3%20Making&recording%20observat.pdf

Data is just data. On its own it is useless. You must analyse this data in order for the information gathered from this data to be useful.

c) identify the orders of magnitude that will be appropriate and the uncertainty that may be present in the measurement of data

This dot point is referring to **accuracy**, which is defined as "The exactness or precision of a measurement; relating to the degree of refinement in measurement or specification." Thus the orders of magnitude of measurements of data is the accuracy of the measurements. This can be explained with the concept of significant figures. I'll assume you all know what decimal places are, you may already know what significant figures are but I will explain them anyway. The number of significant figures you have in a particular quantity is just how many digits you use to make up the quantity, omitting leading zeros. For example the number 52 has two significant figures, that being the '5' and the '2'. The quantity 3.00 has three significant figures, that being the '3', the '0' and the '0'. These three digits define the accuracy of a quantity. For example the quantity 3.00 specifies that the tenths and hundredths of the quantity are zero. This is different to the quantity 3 which means that we only know that the units are 3, we don't know the tenths or the hundredths. And so 3.00 has three significant figures and 3 has one, this means that 3.00 is much more accurate.[1]

When we get to very small numbers such as 0.0001, it is best to explain these in terms of scientific notation. 0.0001 is represented as 1×10^{-4} in scientific notation. They are equivalent. However now

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[1] This concept assumes the scientific context. Mathematically 3.00 and 3 are exactly the same, however in a scientific context 3 means that the value is 3 to one significant figure, the actual number could in fact be 3.45 or 2.99, etc.

that the quantity is in scientific notation we can see only one digit is used to define the quantity, hence is has one significant figures. Now you can see why significant figures are more important than the number of decimal places. Hence when we are measuring data we should ensure that we collect enough significant figures, not decimal places.

However there is another aspect to accuracy. When we measure data, we never know exactly the quantity that we measure. We may measure a length to be 35mm. However the distance may vary from 35mm by ±0.5 and still have this measurement. For example in the diagram below the piece of wood is measured to be 15mm. This is because you can only measure to the lines given, however it is actually a bit greater that 15mm. There is a region of values that are all measured to 15mm, that being from 14.5mm to 15.5mm. Hence the uncertainly of the measurement is ±0.5mm

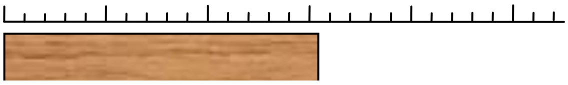


Fig. (2)

So to ensure that we collect accurate data we should use as many significant figures as possible when recording measurements. This also involves making decisions about the equipment to use, for example we can use a standard balance which has an accuracy of 0.001 or an advanced balance that is found at universities that has an accuracy of 0.0000001.

d) identify and use correct units for data that will be collected

SI Base Units:

These are the fundamental measurements, upon which all other measurements are based. However chemistry tends to not always use the SI unit and so the most common units used in chemistry are shown below.

Quantity	Unit	Symbol
Mass	gram	g
Volume	millilitre	mL
Temperature	degrees Celsius	°C
Amount of substance	mole	mol
Molecular Mass	amu	u

For each of these quantities, a standard has been decided upon.

SI Derived Units:

Other units can be defined in terms of the base units. These are known as derived units. For example $\text{speed} = \frac{\text{distance}}{\text{time}}$. As distance and time are base units, the units of speed can be derived from these base units. Hence the unit of speed will be $\frac{\text{metre}}{\text{sec ond}}$, ie. metre per second, ie. ms^{-1}. The units of many quantities can be derived from the formula of that quantity.

Using the SI Prefixes:

Factor	Prefix	Symbol
10^9	giga	G
10^6	mega	M
10^3	kilo	k
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	µ
10^{-9}	nano	n

The above table shows the most commonly used SI prefixes in this chemistry course (although they are rarely needed in the exam). These are used to change units. For example, in many exam questions that require you to calculate the concentration of a substance, they tell you the volume in millilitres (mL). It is best not to put this into the concentration formula, as if you do, you will not get mol L^{-1} for the concentration, you will get mol mL^{-1}.

Using Units in Calculations:
When using formula, there is a simple rule that the units must be the same on both sides, For example $F = ma$, so if we use the units kg and ms^{-2} for mass and acceleration respectively, then the units for force will be $kgms^{-2}$, which is a Newton.

e) recommend the use of an appropriate technology or strategy for data collection or gathering information that will assist efficient future analysis

In modern scientific laboratories data is collected electronically. This is usually done using specialised hardware devices which collect the data, such as data loggers. This data is then sent to a computer where it is analysed using powerful computer software. There are many advantages of this including:

- There is **no chance of human error**. For example if the electronic balance says 5.21g, but then the human accidently records this as 5.12g then a transcription error has occurred. If however the electronic balance sends the 5.21g straight to the computer then there is no chance of a transcription error.

- Humans do not need to be present to monitor the experiment. This means that someone can set up an experiment and get the computer to automatically monitor the experiment and collect data. This is **reduces the labour** needed and means that for experiments that are done over a long time do not need to be sat and watched by a human 24 hours a day.

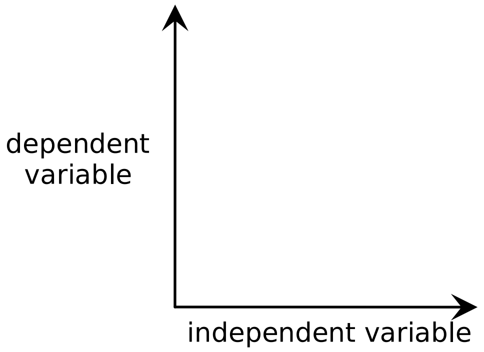
- Humans are not exposed to **potential safety hazards**. For example if you were conducting an experiment which involved radioactive substances, it would be too dangerous to have a human walk into the room and read some measurement. Instead this can be done by a computer and the human can stay outside in a protected room.

Specific technology includes Texas Instruments calculators, which can electronically collect and process data. MATLAB is a software package that can do statistical analysis and process a wide range of data.

11.2 plan first-hand investigations to:

a) demonstrate the use of the terms ”dependent‘ and ”independent‘ to describe variables involved in the investigation

Independent variables, as the name suggests, are variables that do not depend on some other value. For example if you were performing an experiment to model the temperature changes of a cooling body. The independent variable would be time. For every value of time there is a temperature. And so temperature would be the dependent variable. The temperature depends on the time. This relates to functions in mathematics. Where the independent variable is x and the dependent variable is $f(x)$. As such the independent variable is usually plotted on the horizontal axis and the dependent variable on the vertical axis. The independent variable is changed and the dependent variable is measured.



For example, when performing titrations you change the volume of acid in base (or base in acid) and you measure the pH of the substance. So the independent variable is the volume and the dependent variable is the pH.

b) identify variables that need to be kept constant, develop strategies to ensure that these variables are kept constant, and demonstrate the use of a control

For every experiment you should only change one thing at a time and measure one thing. The rest of the variables should be kept constant. If need be you can do an experiment for each of the variables one at a time, ensuring that you never change two variables.

A control is where you leave it unchanged and unaffected by the experiment. This is used so that you have a reference to compare to.

For example, if you wanted to calculate the amount of carbon dioxide in soda water. You could heat the water to change the CO_2 from (aq) to (g). The gas would escape and by weighing the soda water before and after the mass of CO_2 in the soda water can be calculated. However there is a problem with this experiment, some water has evaporated this means that the results are not valid. To make the results valid a control could be used, in which an identical amount of pure water is heated in the same way and temperature as the soda water and the control will tell you how much water has evaporated in the control and this will be the same for the soda water and so this mass of evaporated water can be subtracted to get the mass of CO_2. (See 9.3.2.1 for details of this experiment.)

c) design investigations that allow valid and reliable data and information to be collected

When people think of syllabus topic 9.1 they usually think of reliability, validity and accuracy. However their definitions and explanations differ depending upon their context. This dot point refers to **validity and reliability of first-hand data** (the other context is validity and reliability of secondary sources of information). The Science Years 7-10 Syllabus defines these terms,

Validity of first-hand data	The extent to which the processes and resultant data measure what was intended.
Reliability of first-hand data	The degree with which repeated observation and/or measurements taken under identical circumstances will yield the same results.

To explain this lets imagine that we fired an arrow at the target and our aim was to hit the bulls eye. The four different situations show validity and reliability. Some texts mention accuracy in this. It is difficult to understand what the syllabus means when it refers to accuracy however I think that it refers to the dictionary definition. (This is also the view of Curriculum K-12 Directorate, DET NSW.)[1] The 'Australian Oxford Dictionary' defines accuracy as, "The exactness or precision of a measurement; relating to the degree of refinement in measurement or specification." Thus the diagram below does not show accuracy.

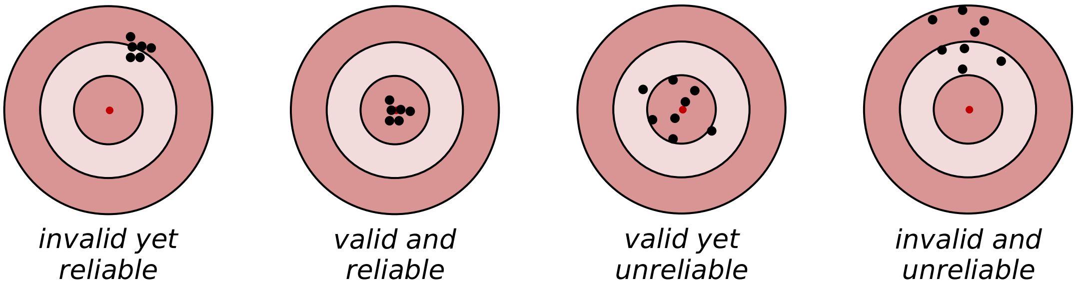

invalid yet reliable *valid and reliable* *valid yet unreliable* *invalid and unreliable*

Fig. (3)

Reliability refers to whether or not you get the same result when you repeat the experiment. It relates to the consistency of results. For example if you perform the same experiment 10 times with the same conditions and each time you get relatively large differences between all 10 results, then your experiment is not very reliable. If however you get the same result all 10 times then your experiment is very reliable. To ensure a reliable experiment you should ensure that the same conditions are met when repeating the experiment.

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[1] Reliability, validity and accuracy - what do they mean? (2006). *Curriculum Support for teaching in Science 7-12* , 11 (2), pp. 5-6.

Validity refers to if the results are correct. A valid experiment is one that fairly tests the hypothesis. To ensure validity ensure that you perform the correct calculations with no conceptual errors, and also ensure that the way you perform your experiment will test and give the correct results for the aim of the experiment. Also you can keep the variables to a minimum. For example it is difficult to establish the link between smoking and lung cancer as there are many variables involved.

However, just because your experiment is very reliable does not mean that it is valid. You may just keep getting the same wrong result all this time. In this case your experiment would be very reliable, but invalid. Similarly your experiment could be extremely valid, yet unreliable. The best experiments are valid and reliable.

d) design and trial procedures to undertake investigations and explain why a procedure, a sequence of procedures or repetition of procedures is appropriate

A procedure is just a sequence of steps that are taken to perform an experiment. A procedure for an experiment is necessary so that others can perform the same experiment as you (ie. repeat it) the same way and under the same conditions. This is necessary as for an experiment to be valid, it must be able to be repeated all the time by different people and still yield the same result.

e) predict possible issues that may arise during the course of an investigation and identify strategies to address these issues if necessary

11.3 choose equipment or resources by:

a) identifying and/or setting up the most appropriate equipment or combination of equipment needed to undertake the investigation

Equipment is the tools you use to perform the experiment. Some of the most common equipment used in this chemistry course includes:

- Beaker
- Test tube
- Electronic Balance
- Conical flask
- Volumetric flask
- Bunsen burner

b) carrying out a risk assessment of intended experimental procedures and identifying and addressing potential hazards

A risk assessment involves investigating and identifying any potential risks or hazards and then implementing methods to eliminate or reduce the risk or hazard. Some common risks/hazards and why they are risks/hazards in this chemistry course include:

- **Glass equipment** can break and shatter causing flying shards of glass. To reduce this risk wear safety glasses and be careful and cautious when handling the fragile equipment.
- **Corrosive chemicals** such as **acids and bases**. These can cause damage to clothes, skin, eyes, etc. To reduce this risk
- **Explosive substances** such as lithium and sodium can undergo reactions that produce large amounts of heat. This can cause an explosion which could injure people.
- **Radioactive substances** or **electromagnetic radiation** can cause cancer to living things. To reduce the risk, ensure methods are taken to label radioactive substances with warning signs, and store them is layer of lead.

It is important to remember the three main aspects of risk assessments.

Identify the risk.
↓
Explain why it is a risk.
↓
Explain measures taken to reduce or eliminate the risk.

In Chemistry you should refer to Materials Safety Data Sheets to determine the risks and how they should be addressed.

c) identifying technology that could be used during investigations and determining its suitability and effectiveness for its potential role in the procedure or investigations

This is explained in H11.1 (e).

d) recognising the difference between destructive and non-destructive testing of material and analysing potentially different results of these two procedures

In destructive testing of materials, the testing process destroys the material. For example if I was testing the pH of a substance using indicators, I would need to keep alter the substance in the process of testing it. As the indicator has changed the substance, the method was destructive. In non-destructive testing the testing process does not alter the material. For example testing the pH of a substance using a pH metre will not affect the substance in the process of testing it.

In some cases destructive testing can affect the results of the experiment. However also in some cases the non-destructive testing methods do no test the material with enough rigor and the results are not entirely accurate or correct. For example if I was testing the pH of a substance using indicators the process of adding the indicator may alter the pH of a substance and thus the results would not be valid.

H12. evaluates ways in which accuracy and reliability could be improved in investigations

12.1 perform first-hand investigations by:

a) carrying out the planned procedure, recognising where and when modifications are needed and analysing the effect of these adjustments

b) efficiently undertaking the planned procedure to minimise hazards and wastage of resources

This is explained in H11.3 (b).

c) disposing carefully and safely of any waste materials produced during the investigation

This is important as waste materials can quite often be dangerous. They may be toxic, corrosive, flammable, radioactive, biohazard, etc. If these dangerous materials are not disposed of properly then the trash bin could explode or cause damage to people or property. Also if these materials are just washed away down the drain (mainly a problem with non-polar substances such as cyclohexane), they could impact on the waterways which may affect marine life and may even contaminate drinking water.

Often special disposal bins are provided for different types of materials. For example at hospital waste body parts are put in special biohazard bins. Also at nuclear reactors radioactive waste is sealed away in thick lead containers and put in the ground with concrete all around it.

d) identifying and using safe work practices during investigations

Safe working practices include handling and disposing materials correctly, using equipment as it was designed to be used and ensuring any trouble makers in your class are placed in a separate room during the practical task so that they do not potentially injure other students.

See also H11.3 (b).

12.2 gather first-hand information by:

a) using appropriate data collection techniques, employing appropriate technologies including data loggers and sensors

This is explained in 11.1 (e)

b) measuring, observing and recording results in accessible and recognisable forms, carrying out repeat trials as appropriate

This means that when you are for example weighting a substance, do not just write down the weight on your hand or try to remember it (like so many of us do). Instead get a piece of paper and construct a table. Then when you go over to weigh a substance you can write in the values on the table with titles labelled. This leads to less chance of forgetting what the measurement was.

Also if you are observing a result it may be best to do it several times. For example if you are recording the smell of an ester, you may want to smell it several times before you record what smell it was.

12.3 gather information from secondary sources by:

a) accessing information from a range of resources including popular scientific journals, digital technologies and the Internet

Scientific journals are where almost all of the new discoveries and theories are published. They are an accurate source of information as the content is peer reviewed. Some of the most popular scientific journals are *Nature*, *Science* and *Scientific American*.

Digital technologies and the internet are also a great source of information. However it must be remembered that information on the internet is not always correct (but then again nor is the information in books). Some sources on the internet are more reliable than others. For example Wikipedia can be considered more reliable than somebody’s personal web page, as many people edit it and review it for correctness and make appropriate changes. But then universities internet sites have content that is written by qualified professionals in their field and therefore the information would be more reliable than some random .com site. Usually if the site is .edu then it can be considered more reliable.

b) practising efficient data collection techniques to identify useful information in secondary sources

When looking at an article or scientific paper for information, it is a good idea to read the introduction, abstract or first paragraph. This will give you an idea what the paper is about and if it is not exactly what you are looking for then you have saved time from reading the whole article.

An example of an efficient data collection technique is shown below.

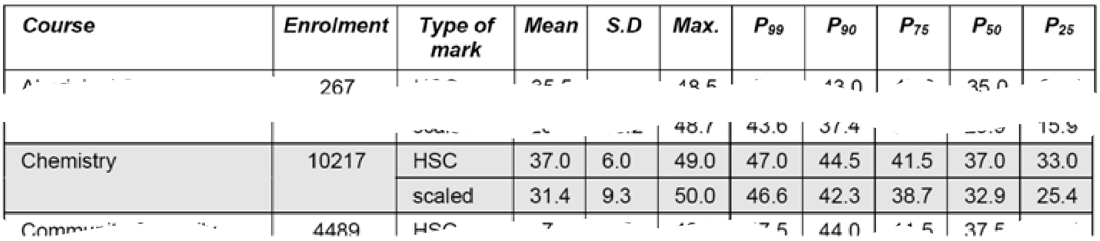
> **The significance of Fritz Haber's work**
>
> **World context:** Nitrogen compounds were is essential for the production of fertilisers and explosives. Much of the fertiliser originated in Chile Much of the worlds fertiliser came from Chilie , a long way from the industrial centres of Europe. It was known that the atmosphere contains large amounts quantities of diatomic nitrogen. It would be advantageous to convert this readily available gas to usable compounds for agriculture and industry, cheaply and on a large scale.
>
> **Haber's contribution:** Fritz Haber had studied under Robert Bunsen, in Germany, and was interested in the effect of heat on the chemistry of gases. In the early 1900s, Haber reacted nitrogen with hydrogen, using an iron catalyst, to form ammonia. Ammonia can be readily converted to a range of valuable products. In 1908 he had improved the reaction and in 1911 he was rewarded with a directorship at a German institute. Carl Bosch developed the chemical engineering necessary for the large-scale production of ammonia by the Haber-Bosch process.
>
> **Significance:** Germany used the process to make explosives in World War I after the British cut off supplies of nitrate from Chile. This lengthened the war.
>
> Information Source: HSC CSU Online

The information on the significance of Fritz Haber's work has been collected from a secondary source, an internet site, HSC CSU Online. I have then efficiently collected data from this source, using the parts that I feel are relevant and omitting the parts that I feel are not. Also I have reworded parts that I feel are unclear or could be explained better.

c) extracting information from numerical data in graphs and tables as well as from written and spoken material in all its forms

Data can be presented in many ways. It could be in a table or a graph or it could be mixed in with a written report or it could be spoken by a lecturer.

For example the information of the scaling of Chemistry by UAC in 2006 is represented in a table. The numerical data can be easily gathered from this table. Presenting data in a table allows for others to take and use this data. For example because this scaling data is presented in a table, the data could be easily and accurately taken for use in Bored of Studies SAM™.



Course	Enrolment	Type of mark	Mean	S.D	Max.	P_{99}	P_{90}	P_{75}	P_{50}	P_{25}
	267				48.5		43.0		35.0	
					48.7	43.6	37.4			15.9
Chemistry	10217	HSC	37.0	6.0	49.0	47.0	44.5	41.5	37.0	33.0
		scaled	31.4	9.3	50.0	46.6	42.3	38.7	32.9	25.4
	4489						44.0			

Report on the Scaling of the 2006 NSW Higher School Certificate, Technical Committee on Scaling,
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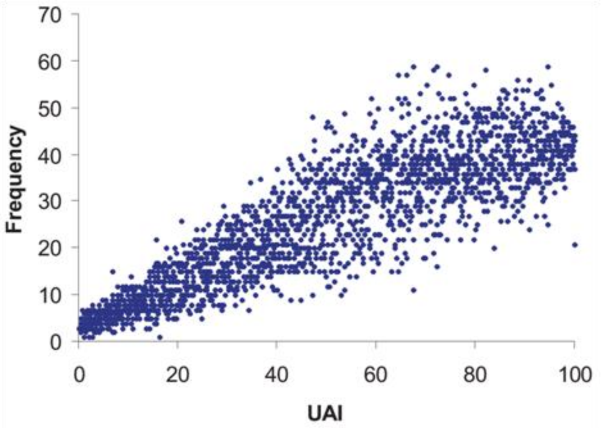
However a table is not always the best method of presenting data. For example the frequency distribution of each UAI for 2005 is represented in a graph shown below. If this data was presented in a table it would be difficult to easily understand and trends would be difficult to see. However, approximate numerical data can still be obtained from the graph (this is not the best example for this).



Report on the Scaling of the 2005 NSW Higher School Certificate, Technical Committee on Scaling, © Universities Admissions Centre 2006

Data can also be represented in written form. For example the extract below from a Report on Scaling of the 2005 HSC, much data is conveyed through this sample paragraph.

> In 2005 the distribution of UAIs was similar to those of previous years (see Table 4.4) for UAIs greater than 70.00, with 15.9% of the UAI eligible students receiving a UAI of 90.00 or above and 31.3% gaining a UAI of 80.00 and above. For lower UAIs the percentages in 2005 were almost identical to those of previous years. In 2005 the median UAI was similar to that of previous years (see Table 4.5).

Report on the Scaling of the 2005 NSW Higher School Certificate, Technical Committee on Scaling, © Universities Admissions Centre 2006

I must stress now that extracting data is not exactly the same as extracting information. In the first example data on the scaling of Chemistry has been extracted. But on its own the data is near useless. To obtain information from this data we need to sometimes perform statistical analysis on the data, or sometimes take into account where the data came from, what the purpose of the data is, etc. For example looking at the mean HSC mark and mean scaled mark in the first example, we cannot say that because the mean HSC mark of 37.0 scales down to 31.4, that Chemistry is a terrible scaling subject and should not be chosen. We have not considered all the other factors about this data. But if we look at how this figure was obtained, and if we compare it to all the other courses we see that, compared to other courses Chemistry scaled quite highly and that we should study it.

d) summarising and collating information from a range of resources

An example of summarising information is shown in H12.3 (b).

It is important to remember that you should collect information from a wide range of sources and then collate all this information together to make sense of it. These syllabus notes are a great example of this. These syllabus notes have been compiled from a wide range of sources as shown in the references section. For example, I have used text books, summary books, web resources and others dot point notes.

e) identifying practising male and female Australian scientists, the areas in which they are currently working and information about their research

12.4 process information to:

a) assess the accuracy of any measurements and calculations and the relative importance of the data and information gathered

Accuracy of measurements refers to the number of significant figures your data is to and the relative error margin of your data.

See also H11.1 (c).

b) identify and apply appropriate mathematical formulae and concepts

The most commonly used mathematical formulae used in this Chemistry course are shown below. How to apply these formulae is Year 7 Mathematics, so I will not go into that. Identifying which formula to use comes by knowledge of the content in this course.

Some useful formulae

$\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$ $\quad\quad$ $\Delta H = -m\,C\,\Delta T$

c) best illustrate trends and patterns by selecting and using appropriate methods, including computer-assisted analysis

A trend or pattern is what appears to be happening from the available data. Trends are best shown by the use of graphs and trend lines. Computers can greatly assist in the analysis of data. They are fast, accurate and can process huge amounts of data. For example the *CERN* particle accelerator which conducts experiments on high-energy particle physics collects huge amounts of data every second (just one of the many detectors will produce more than 60 GB of data every second). Massive computing power must be used to process the huge amounts of data collected to make it useful. However this is a long way off that done in the high school Chemistry laboratory.

Trend Analysis may be done by either hand or computer-assisted methods. If done by hand you may use your own judgement on trend lines, or you may do the calculations to work out the trend line. Computer software packages that are used to analyse data include MATLAB and Microsoft Excel.

When you graph the dependent variable against the independent variable you plot the point of the data you collect. For example the graph below shows the data collected from an experiment shown in the table and a line of best fit drawn by human judgement. The blue line is the line of best fit (linear regression). It is a trend line.

Time (sec)	Displacement (m)
0	0
2	1.4
4	1.8
6	3
8	5
10	5.8
12	5.6

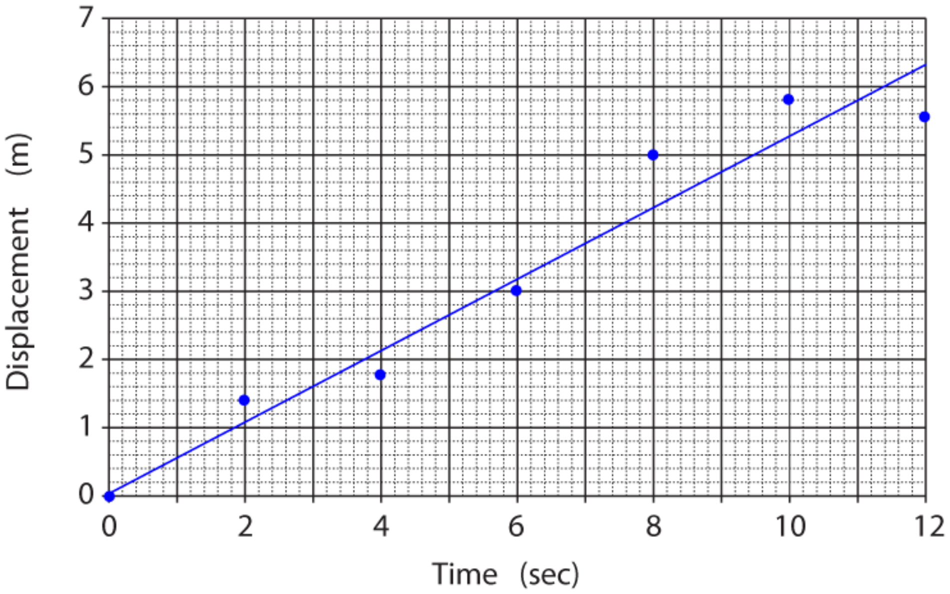


Fig. (4)

Trend lines are not always linear. For example population increase in a country would need exponential trend line. A linear trend line would not show the trend accurately. A very good example of a non-linear trend is titration curves.

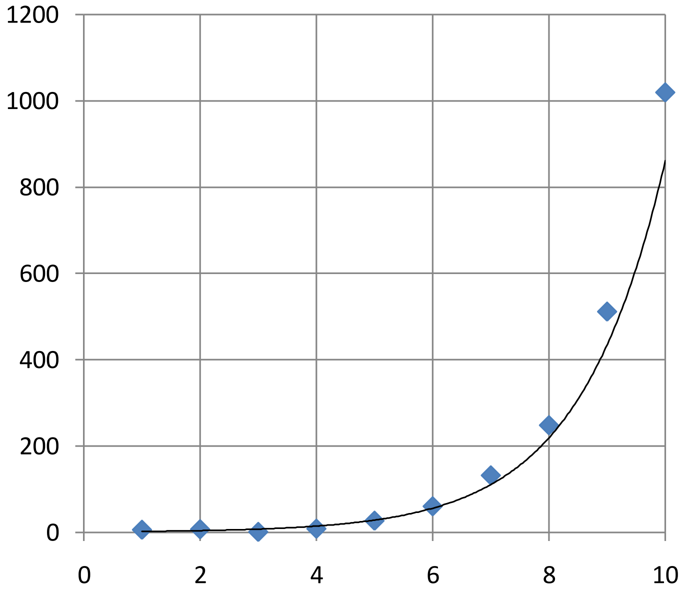


Fig. (5)

If you know the mathematical model that defines the data that you are collecting, then your trend line should use that equation. However the mathematical model is not always known and often it is the data you collect that leads to the mathematical model.

Trend lines try to eliminate the small variations or errors that come with collecting data. Trend lines can be used to interpolate data (find values in between two know values) or extrapolate data (predict what will happen for values not in the tested domain, eg. in the first graph what will happen at time = 14 sec.).

d) evaluate the relevance of first-hand and secondary information and data in relation to the area of investigation

Not all the data and information you collect is relevant. You must make a judgement as to whether the information and/or data is relevant to your investigation.

e) assess the reliability of first-hand and secondary information and data by considering information from various sources

The term reliability used here is different to the term used in the context of first-hand investigation. This term is used here in the context of gathering information and data. As such it has a slightly different meaning.

The reliability of first-hand and secondary information and data refers to collecting information and data from a **range of reputable sources** and **make comparisons** between the information and data collected.

f) assess the accuracy of scientific information presented in mass media by comparison with similar information presented in scientific journals

As mentioned in H12.3 (a), scientific journals are usually written by qualified scientists and are peer reviewed. On the other hand, information presented in the mass media (eg. newspaper/TV reports), can often bend the data to make it appear something that it is not. And so information presented in scientific journals is usually much more accurate than information presented by the mass media.

H13. uses terminology and reporting styles appropriately and successfully to communicate information and understanding

13.1 present information by:

a) selecting and using appropriate text types or combinations thereof, for oral and written presentations

Written presentations in Chemistry use the report text type. As such a chemistry paper or report should contain features such as an abstract, body and references. If the paper or report is presenting information on an experiment, then features such as procedure, results, conclusion, etc. should be present. Appendices may also be used to present information, especially the raw data collected, that may be not be necessary to understand the report or the data may be too long and too great.

Oral presentations, such as seminars, lectures or talks, may also contain visuals such as a slide show that accompanies the talk. This allows people listening to also see any visuals such as graphs that are related to what the speaker is talking about.

b) selecting and using appropriate media to present data and information

Information can be presented though conferences, magazine articles, journal publications, newspapers, online articles, published reports, etc.

c) selecting and using appropriate methods to acknowledge sources of information

When writing a report it is important to acknowledge sources of information. This is done in the references/bibliography section. There are many conventions on how to acknowledge a source, one method is shown below.

> Yang, Y., (2003) "Dimensions of Socio-economic Status and Their Relationship to Mathematics and Science Achievement at Individual and Collective Levels", *Scandinavian Journal of Educational Research*, 47, 1, 21-41

d) using symbols and formulae to express relationships and using appropriate units for physical quantities

This involves using formula and equations to represent relationships among variables. Some symbols that are used in chemistry that you should be aware of are,

Symbol	Words	Explanation
Δ	Delta	Change in a quantity. i.e. $final - initial$
$[X]$	Square Brackets	This indicates the concentration of X.
$\boldsymbol{n}(X)$	Number of moles	This indicates the number of moles of X.
$\rightarrow$	Arrow	The reaction goes to completion.
$\rightleftharpoons$	Equilibrium Arrow	The reaction is an equilibrium reaction.

See H12.4 (b) and H11.1 (d).

e) using a variety of pictorial representations to show relationships and presenting information clearly and succinctly

This involves using graphs and illustrations to represent relationships among variables, without any ambiguity. It also involves using the type of graph that is relevant. For example it is not appropriate to use a sector (pie) graph to graph the variation in temperature over a day. Line and scatter graphs are used for continuous independent variables and column and pie graphs are used when the independent variable is discreet.

f) selecting and drawing appropriate graphs to convey information and relationships clearly and accurately

Different types of graphs are used for different purposes. Some of the different types of graphs are shown below. The scatter graph is the most common graph type in chemistry.

Microsoft Excel 2007

Some key things to remember when drawing graphs include: (they frequently ask you to draw graphs in the exam and these are some of the things that you are assessed on)

- Always place the **independent variable on the horizontal axis (x)** and the **dependent variable on the vertical axis (y)**.

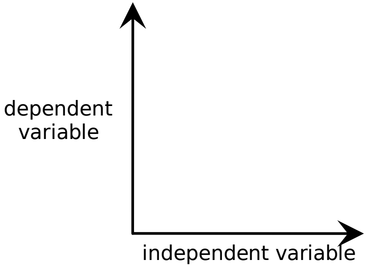


Fig. (6)

- Mark each axis with the **quantity** that is being changed/measured and include the **units**.

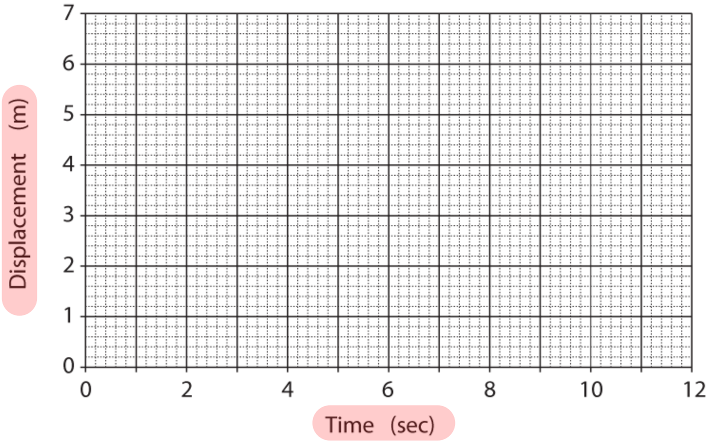


Fig. (7)

- The axis should be labelled with a **scale**. This scale should be linear, however in some special cases a non-linear scale can be used.

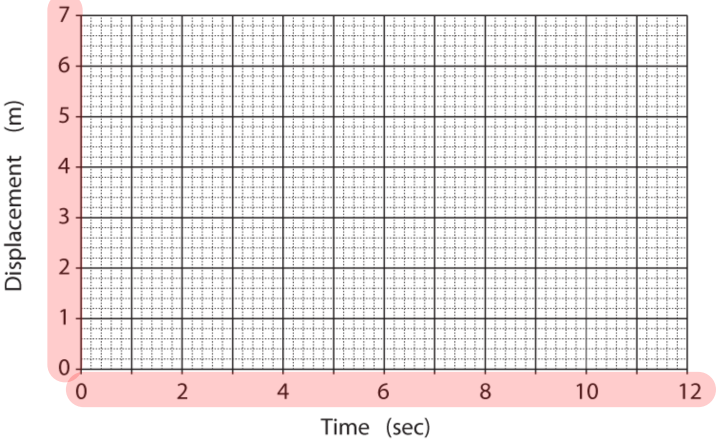


Fig. (8)

- Points from the data should be represented on the graph as dots. You should also join these dots, using linear interpolation if the data being represented is continuous.[1]

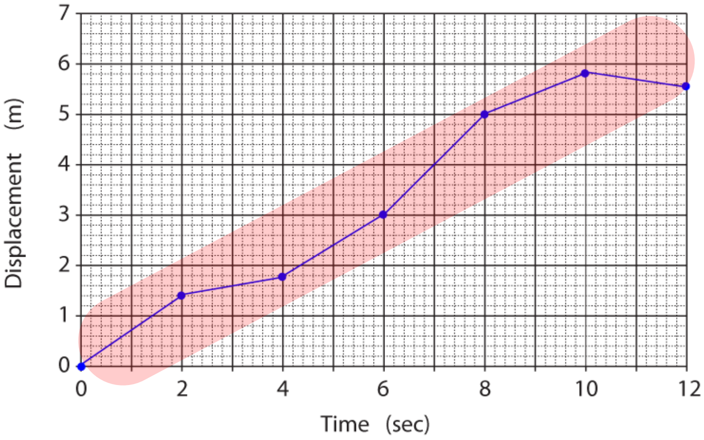


Fig. (9)

- You should also draw either a **line or curve of best fit** (line is the safest option in the exam). Even if the question did not ask for a trend line[2]. Outliers should be ignored in the line of best fit.

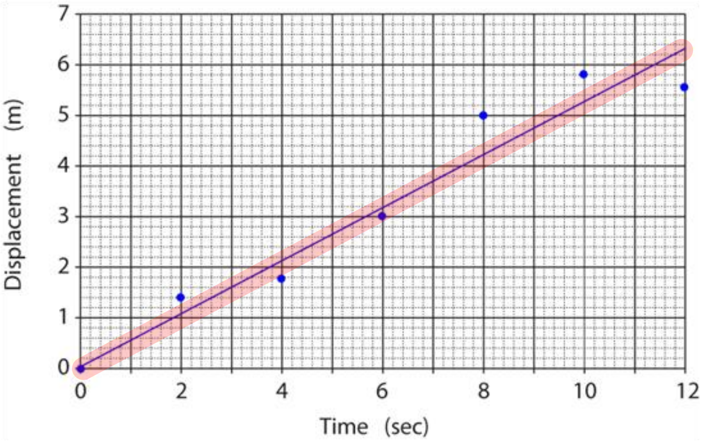


Fig. (10)

- Depending upon what the data you are collecting is, the graph usually passes though the origin (0,0). However be sure to thing about this before you go ahead and do it. Think to yourself, what would the y value be when $x = 0$?

Plotting points, or reading values from plotted points sounds easy but can sometimes be a little tricky. The diagram below shows the simplest case, where each labelled value is one unit and has 10 subdivisions, hence if you were to measure the blue it would be 1.2.

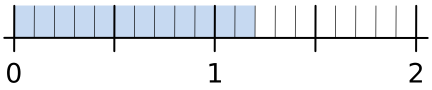


Fig. (11)

The next diagram shows the next type, where again we can see that each subdivision is 0.2 hence the blue would be measured to be 2.4.

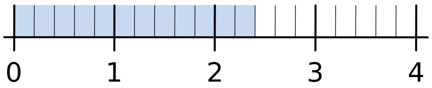


Fig. (12)

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[1] As noted in (Gould & Morante, 2007) you do not always join the dots to form a line graph. For example if you plot the temperature at midday each day for a month, then you should not join the dots. "The points on the line joining the dots is not a good indicator of the temperature at points much removed from midday so there should not be a line connecting these two points."

[2] 2006 Chemistry HSC Exam + Marking Guidelines, Question 25 (a). Board of Studies NSW.
2005 Chemistry HSC Exam + Marking Guidelines, Question 22 (a). Board of Studies NSW.
2003 Chemistry HSC Exam + Marking Guidelines, Question 28 (a). Board of Studies NSW.

A slightly more difficult example is shown below, and although you can still work it out using the above methods, sometimes in the stress of the exam it is best to take a systematic approach. For the example shown below, you can calculate that one subdivision will be $\frac{0.01}{5}$, thus the measurement will be $0.02 + 2 \times \frac{0.01}{5} = 0.024$.

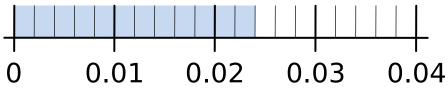


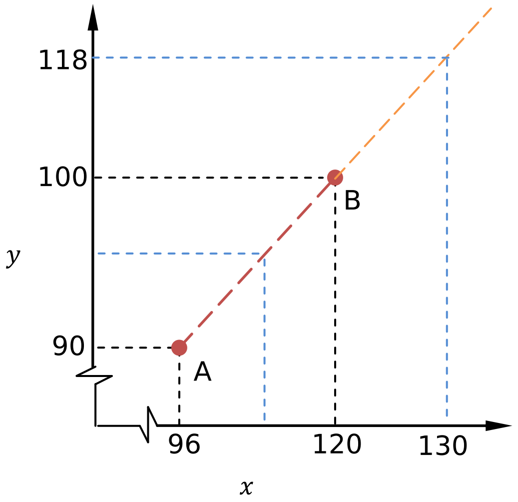
Fig. (13)

g) identifying situations where use of a curve of best fit is appropriate to present graphical information

Depending upon what data you are representing and what the point you have collected look like sometimes a curve of best fit is needed rather than a line of best fit. Some common types of regression are listed below.

Type	Equation
Linear	$y = mx + b$
Exponential	$y = Ae^x$
Power	$y = x^n$
Sine/Cosine	$y = a\sin(nx + \alpha)$
Polynomial	$y = Ax^n + Bx^{n-1} + \cdots$

Curves of best fit allow you to interpolate data (find values in between known values) and extrapolate data (find data outside the known range of values). For example just say we know the two points A and B, but we want to know that the y value will be when x is half way between A and B, well we can use linear interpolation to find this value. Similarly if we want to find the y value when $x = 130$, then we can use extrapolation methods to find the y value. Interpolation is usually more reliable than extrapolation.



H14. assesses the validity of conclusions from gathered data and information

14.1 analyse information to:

a) identify trends, patterns and relationships as well as contradictions in data and information

See H12.4 (c).

Contradictions in data are when one source of data says one thing and another source says the opposite.

b) justify inferences and conclusions

An inference is an educated guess that cannot be proved. For example if I see a car driven furiously out of a car sale yard, I may infer that that car was stolen. However I cannot prove that. It may have been stolen or they may just have been taking it out for a test drive. However it is a hypothesis, because I have made this conclusion about the car being stolen based on the evidence that the car was being driven furiously.

c) identify and explain how data supports or refutes an hypothesis, a prediction or a proposed solution to a problem

A hypothesis is your opinion. What you think is happening. You then test your hypothesis to either prove it right or wrong. For example I may have a hypothesis that no one contributes to the Bored of Studies Wiki. I then have to perform an investigation to test my hypothesis. So I will go and look at the recent changes and see that no one has contributed for a week. Hence I may conclude that my hypothesis is correct. I have used the data of the recent changes to test my hypothesis, and the data supports it.

Similarly if I make a prediction or a proposed solution to a problem, I need to then obtain the relevant data to support or refute that proposal or prediction.

d) predict outcomes and generate plausible explanations related to the observations

e) make and justify generalisations

Generalisations are when you observe something for a small sample and you say that the same will apply for everyone. For example, if land on Antarctica and all the penguins that I can see are black and white then I can make a generalisation that all penguins on Antarctica are black and white. This generalisation may be true but I cannot know for sure unless I track down every single penguin.

f) use models, including mathematical ones, to explain phenomena and/or make predictions

A model is just something that represents what is happening in real life. Mathematical models are often made to explain phenomena. These mathematical models can be used to make predictions. Non-mathematical models can also be used such as physical models of the planets orbiting the sun.

> Science attempts to explain phenomena or predict events by identifying consistent trends and patterns from which can be generated a:
>
> - **model**: a mathematical, physical, experimental or logical representation based on a simplified set of assumptions. Models are often elaborated to develop theories;
> - **theory**: a coherent explanation of a body of experimental evidence, based upon a small number of assumptions. A theory provides predictions that can be tested against observations;
> - **law**: a simple and precise statement that has, at one time, been regarded to be universally valid. It describes phenomena that occur with unvarying regularity under the same conditions.

Board of Studies NSW. (1999). *Science Stages 4–5 Syllabus*. Board of Studies NSW. p13.

g) use cause and effect relationships to explain phenomena

Phenomena are something that you observe to be happening. So I may notice the phenomena that when I drop an apple, it falls to Earth. I can explain this phenomenon with a cause effect relationship. That is, the effect of the apple falling is caused by the force of gravity between the apple and Earth.

h) identify examples of the interconnectedness of ideas or scientific principles

14.2 solve problems by:

a) identifying and explaining the nature of a problem

b) describing and selecting from different strategies those which could be used to solve a problem

c) using identified strategies to develop a range of possible solutions to a particular problem

d) evaluating the appropriateness of different strategies for solving an identified problem

Problems can be solved mathematically, through iterative or algebraic processes, or through logical reasoning and experimentation, or many other methods.

14.3 use available evidence to:

a) design and produce creative solutions to problems

b) propose ideas that demonstrate coherence and logical progression and include correct use of scientific principles and ideas

c) apply critical thinking in the consideration of predictions, hypotheses and the results of investigations

d) formulate cause and effect relationships

9.2

PRODUCTION OF MATERIALS

Contextual Outline:

Humans have always exploited their natural environment for all their needs including food, clothing and shelter. As the cultural development of humans continued, they looked for a greater variety of materials to cater for their needs.

The twentieth century saw an explosion in both the use of traditional materials and in the research for development of a wider range of materials to satisfy technological developments. Added to this was a reduction in availability of the traditional resources to supply the increasing world population.

Chemists and chemical engineers continue to play a pivotal role in the search for new sources of traditional materials such as those from the petrochemical industry. As the fossil organic reserves dwindle, new sources of the organic chemicals presently used have to be found. In addition, chemists are continually searching for compounds to be used in the design and production of new materials to replace those that have been deemed no longer satisfactory for needs.

This module increases students' understanding of the implications of chemistry for society and the environment and the current issues, research and developments in chemistry.

X

1. Fossil fuels provide both energy and raw materials such as ethylene, for the production of other substances

1. construct word and balanced formulae equations of chemical reactions as they are encountered

Word Equation: $Hydrochloric\ Acid + Sodium\ Hydroxide \rightarrow Sodium\ Chloride + Water$
Balanced Formula Equation: $HCl + NaOH \rightarrow NaCl + H_2O$

The reactants appear on the left hand side and the products appear on the right hand side of the equation.

$$reactant + reactant \rightarrow product + product$$

The states of the products/reactants are represented by the symbol in brackets after the molecule. (s) = solid; (l) = liquid; (g) = gas; (aq) = aqueous or dissolved in water.

2. identify the industrial source of ethylene from the cracking of some of the fractions from the refining of petroleum

Ethylene is also known as Ethene, C_2H_4, they are the same. Ethylene is a colourless gas. It is flammable with a low solubility in water. The structural formula of ethylene is,

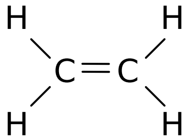


Fig. (14)

Cracking is when long chain carbon molecules are broken down into shorter chains. This is done with the help of a catalyst (catalytic cracking) or heat (thermal cracking), usually steam.

Ethylene can be produced by the thermal cracking of ethane at very high temperatures. Ethane is obtained from the fractional distillation of petroleum.

$$C_2H_6(g) \xrightarrow{steam} C_2H_4(g) + H_2(g)$$

Or represented graphically,

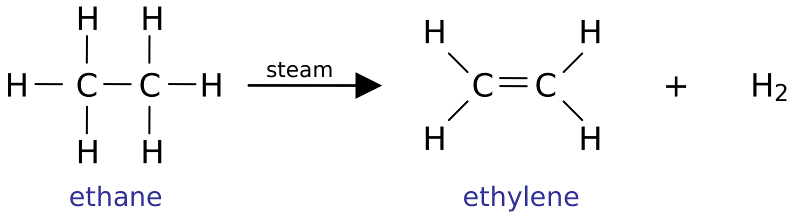


Fig. (15)

3. identify that ethylene, because of the high reactivity of its double bond, is readily transformed into many useful products

As seen above ethylene has a double bond. This makes it highly reactive which means that it can be readily transformed into many other products such as ethanol or polyethylene. For example,

$C_2H_4 + H_2O \rightarrow C_2H_5OH$ (production of **ethanol**)
$\cdots + C_2H_4 + C_2H_4 + \cdots \rightarrow \cdots CH_2CH_2 \cdots$ (production of **polyethylene**)

4. identify that ethylene serves as a monomer from which polymers are made

A monomer is a short chain molecule. A polymer is made up of many identical monomers joined together.

$$\cdots + \text{monomer} + \text{monomer} + \text{monomer} + \cdots \rightarrow \text{polymer}$$

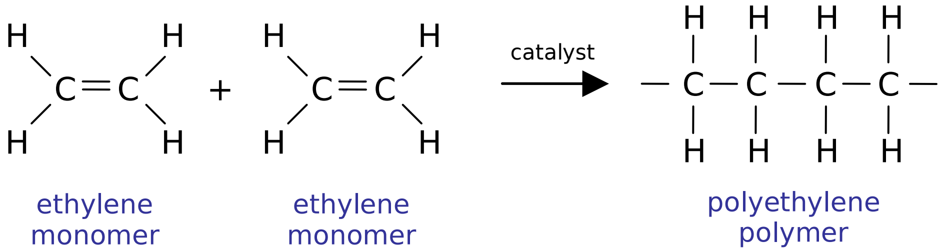


Fig. (16)

5. identify polyethylene as an addition polymer and explain the meaning of this term

An *addition polymer* is a polymer formed by the adding of monomers together, where there are no other products formed apart from the polymer, as shown below.

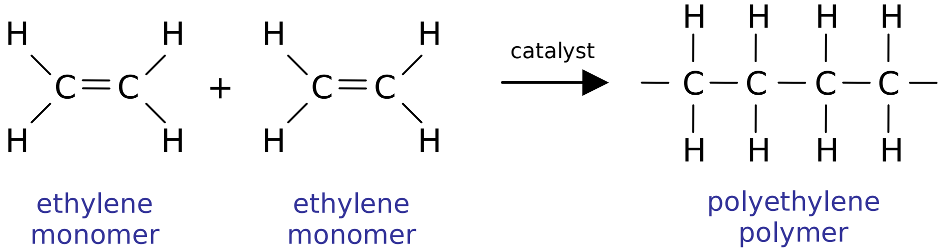


Fig. (17)

6. outline the steps in the production of polyethylene as an example of a commercially and industrially important polymer

The process of making a polymer from a monomer is known as polymerisation.

To make polyethylene from ethylene, a catalyst is added to break the double bond; this leaves electrons to be shared with nearby molecules. They then join together and make a long chain molecule, polyethylene.

From start to end the production of polyethylene is as follows,

$$petroleum \xrightarrow{fractional\ \ distillation} ethane \xrightarrow{thermal\ \ cracking} ethylene \xrightarrow{addition\ \ polymerisation} polyethylene$$

Polyethylene is commercially and industrially important as it is used in things such as shopping bags, toys, glad wrap, etc.

7. identify the following as commercially significant monomers: by both their systematic and common names

- vinyl chloride

Vinyl chloride (chloroethene) is the monomer used to make the polymer polyvinylchloride, **PVC**.
common name *systematic name*

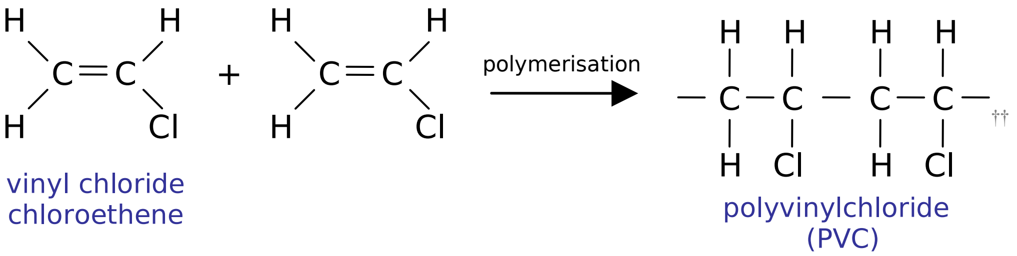
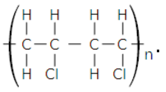


Fig. (18)

[††] There are several ways of representing the polymerisation process. Some text books use brackets. “The better responses showed two or more monomer units joined together rather than the simple abbreviated structure and the bonds at each end of the chain open without the use of ‘n’ molecules.” Board of Studies NSW. (2005). *2004 HSC Notes from the Examination Centre – Chemistry.* Board of Studies NSW.

i.e. They would prefer you NOT use the convention of representing a polymer as, .

PVC is an addition polymer as PVC is the only product from the polymerisation.

- styrene

Styrene (ethenylbenzene[‡‡]) is the monomer used to make the polymer **polystyrene**.
common name, systematic name

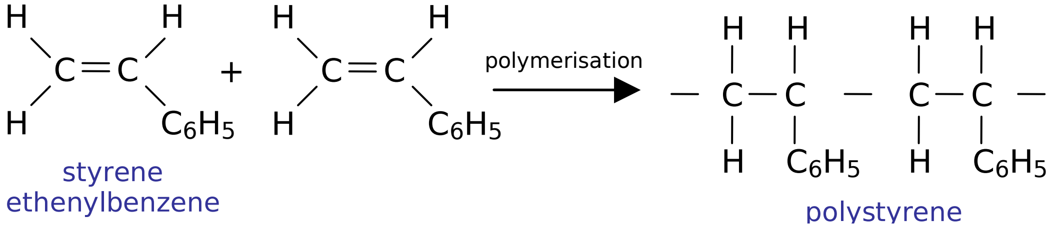


Fig. (19)

Polystyrene is an addition polymer as polystyrene is the only product from the polymerisation. The C_6H_5 is known as the benze ring sometimes represented as shown in the structure of styrene below,

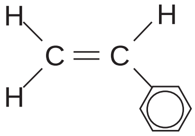


Fig. (20)

8. describe the uses of the polymers made from the above monomers in terms of their properties

Polymer	Use	Property
Polyvinylchloride (PVC)	Electrical Wire Coating	Electrical insulator. Tough and flexible.
	Water Pipes	Impermeable and doesn't corrode. Tough. Easy to manufacture in long tubes.
Polystyrene	Foam Cups	Good insulator of heat.
	Packaging	Absorbs impact. Strong in compression.

1. gather and present information from first-hand or secondary sources to write equations to represent all chemical reactions encountered in the HSC course

This means that in the exam, write chemical equations in your responses wherever possible.

2. identify data, plan and perform a first-hand investigation to compare the reactivities of appropriate alkenes with the corresponding alkanes in bromine water

Alkanes and alkenes react differently when mixed with bromine water, and so it can be used to test if a substance is an alkene or alkane. Bromine water (which has a red-brownish colour) is Br_2, however it has water added to dilute it. The alkane (which has a single bond) will only decolourise the bromine water in the presence of UV light and it takes a long time. The alkene (which has a double bond) will turn the bromine water colourless after about 1 minute, this is due to the highly reactive double bond.

[‡‡] Also known as phenylethene.

Alkane: (Substitution Reaction)

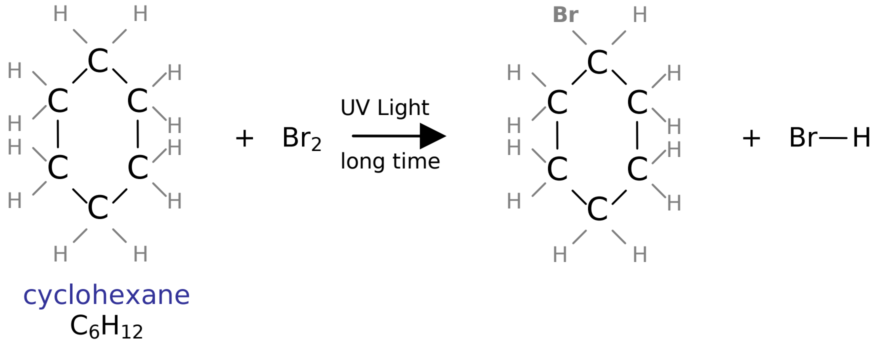


Fig. 21

$$C_6H_{12} + Br_2 \xrightarrow{uv\ light} C_6H_{11}Br + HBr$$

The above reaction is **a substitution reaction** because one of the hydrogen atoms has been replaced with a bromine atom. The bromine water took a long time to decolourise.

Alkene: (Addition reaction)

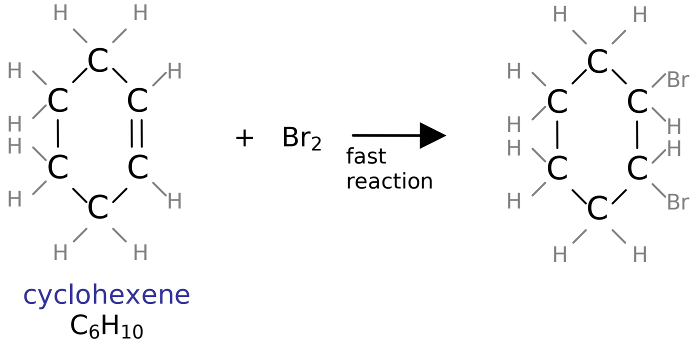


Fig. 22

$$C_6H_{10} + Br_2 \rightarrow C_6H_{10}Br_2$$

The above reaction is an **addition reaction**. The double bond in the hexene has broken, and the Br has attached to the cyclohexane. The bromine water decolourised in about 1 minute. This fast decolourisation of the bromine water tells us that it is an alkene.

Remember that you can only do this test for liquid alkanes and alkenes. It doesn't work with gasses.

3. analyse information from secondary sources such as computer simulations, molecular model kits or multimedia resources to model the polymerisation process

The polymerisation process can be modelled using molecular model kits (i.e. ball and stick models).

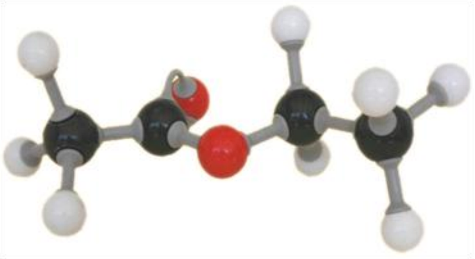


Fig. 23

2. Some scientists research the extraction of materials from biomass to reduce our dependence on fossil fuels

1. discuss the need for alternative sources of the compounds presently obtained from the petrochemical industry

Currently fossil fuels are used as fuel. However fossil fuels are non-renewable and they will eventually run out. So we need an alternative fuel that is renewable. Ethanol is one such fuel that can be used as it can be obtained from the sugar cane plant.

2. explain what is meant by a condensation polymer

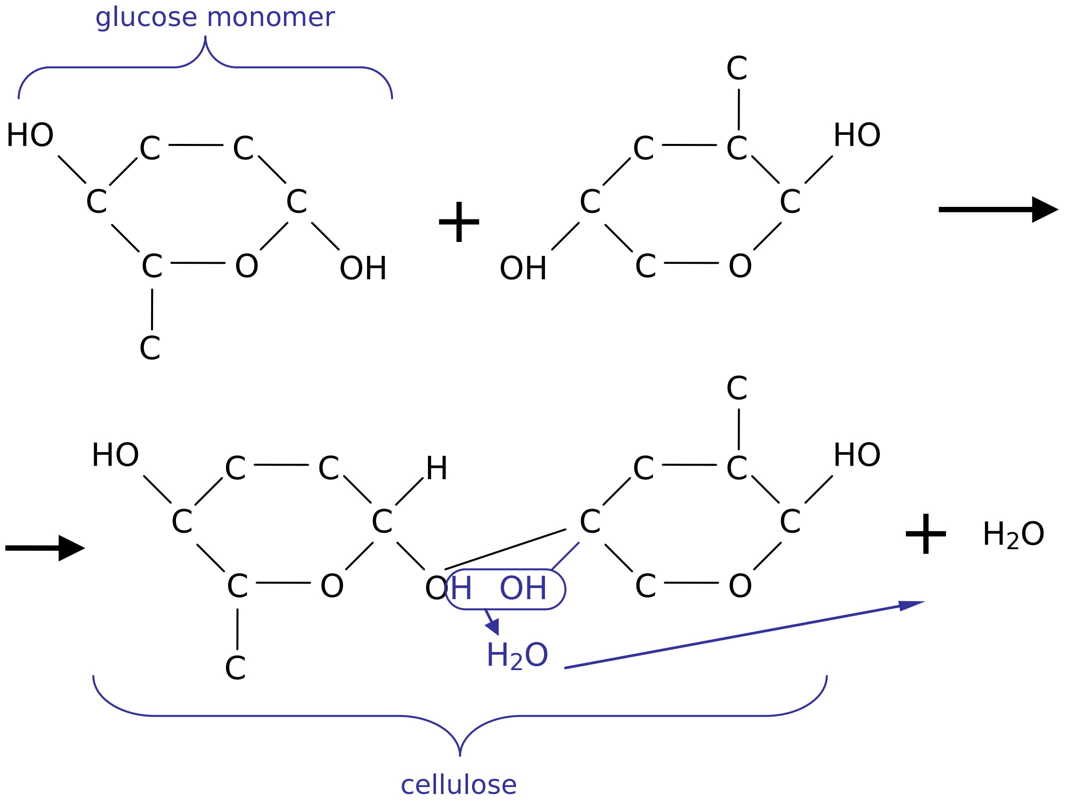
A condensation polymer is a polymer formed from the addition of monomers to form a long chain, which releases a small molecule such as water.

3. describe the reaction involved when a condensation polymer is formed

… + monomer + monomer + monomer + … → polymer + H_2O

4. describe the structure of cellulose and identify it as an example of a condensation polymer found as a major component of biomass

Cellulose is a polymer formed by the glucose monomer. It is produced by condensation polymerisation.



[1] Fig. 24

The HOH forms H_2O, and the remaining O bonds with the C. This happens to all the glucose monomers to from a long cellulose chain, shown below. You should note that the O's that join the monomers are alternating, up/down.

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[1] The structure of the glucose monomer may have been simplified, however you do not need to know the structure of the glucose monomer. The simplified version has been used to show the production of H_2O.

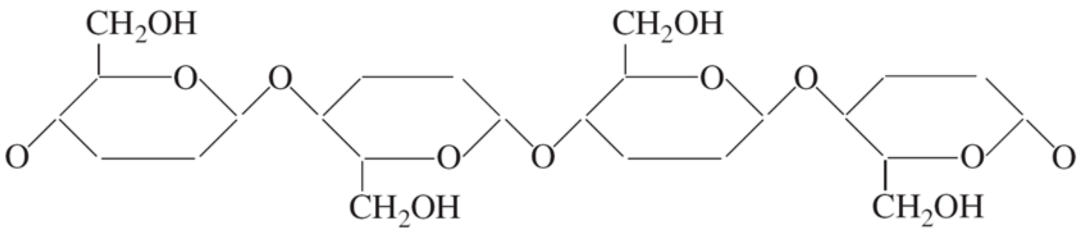


Fig. 25

5. identify that cellulose contains the basic carbon-chain structures needed to build petrochemicals and discuss its potential as a raw material

As a raw material cellulose is a source of 6 carbon-chained molecules which are used in fuels. As cellulose is made by photosynthesis, it can be produced easily and is a renewable resource. This gives it potential for use in fuels. However currently raw cellulose cannot be used as a fuel.

1. use available evidence to gather and present data from secondary sources and analyse progress in the recent development and use of a named biopolymer. This analysis should name the specific enzyme(s) used or organism used to synthesise the material and an evaluation of the use or potential use of the polymer produced related to its properties

Biopol is a recently developed biopolymer. It is produced from the PHA enzyme. Biopol has huge potential for medical use, but also industrially. It use in medicine can be related to its properties. It is biocompatible. This means that it can be placed in the human body and the body will not reject it. It will be treated as part of the body. This makes it useful in artificial organs and skin grafts. Also because it is biodegradable it can be used for suches and stitches. Because it is a renewable resource and easily biodegradable it has potential use as in industry as a polymer. However currently it is more expensive to produce than current polymers, hence it is only used where necessary. However in the future this may change and may be used widespread due to its excellent properties.

3. Other resources, such as ethanol, are readily available from renewable resources such as plants

1. describe the dehydration of ethanol to ethylene and identify the need for a catalyst in this process and the catalyst used

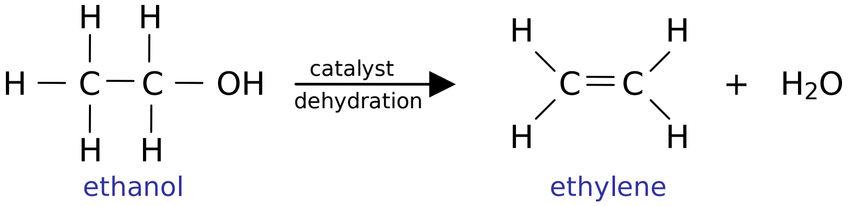


Fig. 26

$$C_2H_5OH(g) \xrightarrow{conc.\,H_2SO_4} C_2H_4(g) + H_2O(g)$$

The catalyst used is **concentrated sulfuric acid** (H_2SO_4) and high temperatures. Concentrated sulfuric acid is needed because the double bond in ethylene is highly reactive and doesn't want to form easily. The sulfuric acid acts as a dehydrating agent.

2. describe the addition of water to ethylene resulting in the production of ethanol and identify the need for a catalyst in this process and the catalyst used

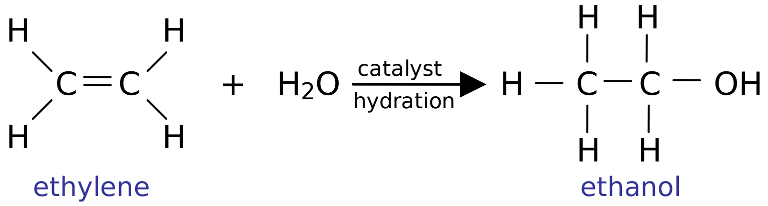


Fig. 27

$$C_2H_4(g) + H_2O(g) \xrightarrow{dil.\,H_2SO_4} C_2H_5OH(g)$$

The catalyst used is **dilute sulfuric acid** (H_2SO_4) and high temperatures. Only dilute sulfuric acid is needed because of the highly reactive double bond, which already wants to break down.

3. describe and account for the many uses of ethanol as a solvent for polar and non-polar substances

Because ethanol dissolves in both polar and non-polar substances, it is used as a **cleaning agent**.

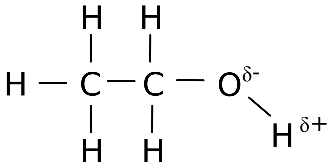


Fig. 28

Ethanol dissolves in both polar and non-polar substances due to its structure. It has a non-polar CH_3 end on one side and a hydroxyl group at the other end. The **CH_3** end can dissolve **non-polar** substances due to **dispersion forces**, and the **OH** end can dissolve **polar** substances due to **hydrogen bonding**.

4. outline the use of ethanol as a fuel and explain why it can be called a renewable resource

Ethanol can be called a renewable resource because when used as a fuel the product produced is CO_2. This is a greenhouse gas and although bad, the plants that produce the sugar used to make the ethanol use up the CO_2, and so it can be considered a renewable resource. The combustion of ethanol is shown as follows,

$$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(l) + energy$$

Ethanol can be produced by the **fermentation of sugar** or **hydration of ethylene**. Ethylene can be produced by the thermal cracking of ethane.

5. describe conditions under which fermentation of sugars is promoted

Sugar solution undergoes fermentation in the presence of a catalyst, **yeast**. Fermentation takes several days, and works best at **warm temperatures** and with **low O_2 concentration**.

6. summarise the chemistry of the fermentation process

The fermentation process involves adding yeast to sugar in solution and leaving it for several days, in warm temperatures (30°C) in low concentrations of O_2. It will give off CO_2 gas. The remaining liquid is a mixture of ethanol and water, which can be distilled to get pure ethanol.

$$\mathrm{C_6H_{12}O_6}(aq) \xrightarrow{yeast} \mathrm{2C_2H_5OH}(aq) + \mathrm{2CO_2}(g) + heat$$

7. define the molar heat of combustion of a compound and calculate the value for ethanol from first-hand data

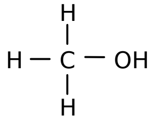
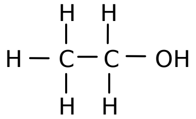
The molar heat of combustion of a compound is the amount of heat energy given off or gained per mole, when it is burned. *See blue dot point 6 for calculations.*

8. assess the potential of ethanol as an alternative fuel and discuss the advantages and disadvantages of its use

Advantages	Disadvantages
• **Renewable** resource. (as it can be produced by fermentation glucose, obtained from sugar cane plant) • The sugar cane uses up some of the CO_2 produced by the combustion of the ethanol. Hence it is better for the environment. • Any spillages that occur will mix with the water and become very dilute. (Because ethanol, due to the OH is **soluble in water**) This avoids environmental disasters. At most a few fish will become drunk.	• Large areas of **land** are required for production of sugar cane plant. • **Spillages** mix in with water, they do not float on top, this means that it is extremely difficult to contain spillages. The ethanol is usually lost. • Currently production of ethanol is **more expensive** than extraction of fuels from fossil fuels. • Lower energy density. • Disposal of waste fermentation products can be a problem.

Ethanol has future potential for use as an alternative fuel, however currently use as an additive is suitable.

9. identify the IUPAC[1] nomenclature for straight-chained alkanols from C1 to C8

Carbon Chain	IUPAC Name	Structural Formula	Graphical Structural Formula
C1	**Methanol**	CH_3OH	 $\mathrm{H-\underset{H}{\overset{H}{C}}-OH}$
C2	**Ethanol**	C_2H_5OH	 $\mathrm{H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-OH}$

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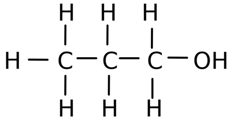
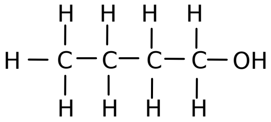
[1] "The International Union of Pure and Applied Chemistry (IUPAC) provides a system for the clear communication of chemical nomenclature with an explicit or implied relationship to the structure of compounds. Nomenclature based on IUPAC principles is designed to name organic compounds unambiguously.

'Preferred IUPAC names' are those developed using the rules put forward by IUPAC, or in some instances are well established trivial names such as acetic acid. The existence of a preferred IUPAC name for a chemical compound does not prohibit the use of other names that have been derived by a systematic process and are unambiguous. For example, while but-2-ene is a preferred IUPAC name, 2-butene is also allowed under IUPAC rules." Board of Studies NSW. (2002). *Stage 6 Chemistry Syllabus 2002*. Board of Studies NSW. pg. 95.

C3	**Propanol**	C_3H_7OH	
C4	**Butanol**	C_4H_9OH	
C5	**Pentanol**	$C_5H_{11}OH$	etc.
C6	**Hexanol**	$C_6H_{13}OH$	etc.
C7	**Heptanol**	$C_7H_{15}OH$	etc.
C8	**Octanol**	$C_8H_{17}OH$	etc.

1. process information from secondary sources such as molecular model kits, digital technologies or computer simulations to model:

- the addition of water to ethylene

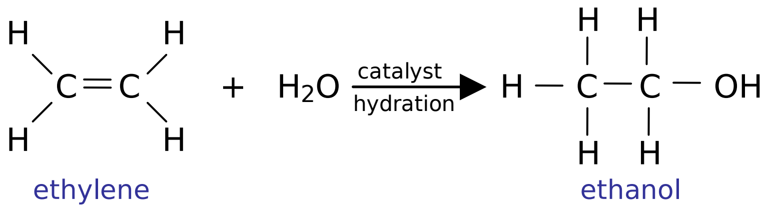


Fig. 29

- the dehydration of ethanol

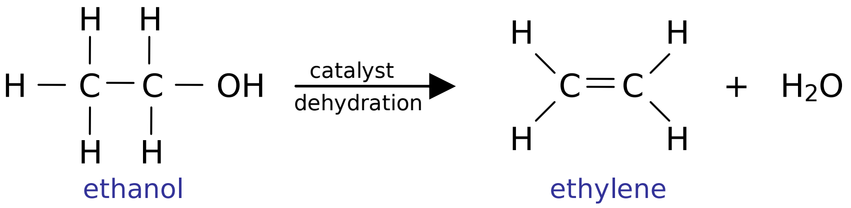


Fig. 30

2. process information from secondary sources to summarise the processes involved in the industrial production of ethanol from sugar cane

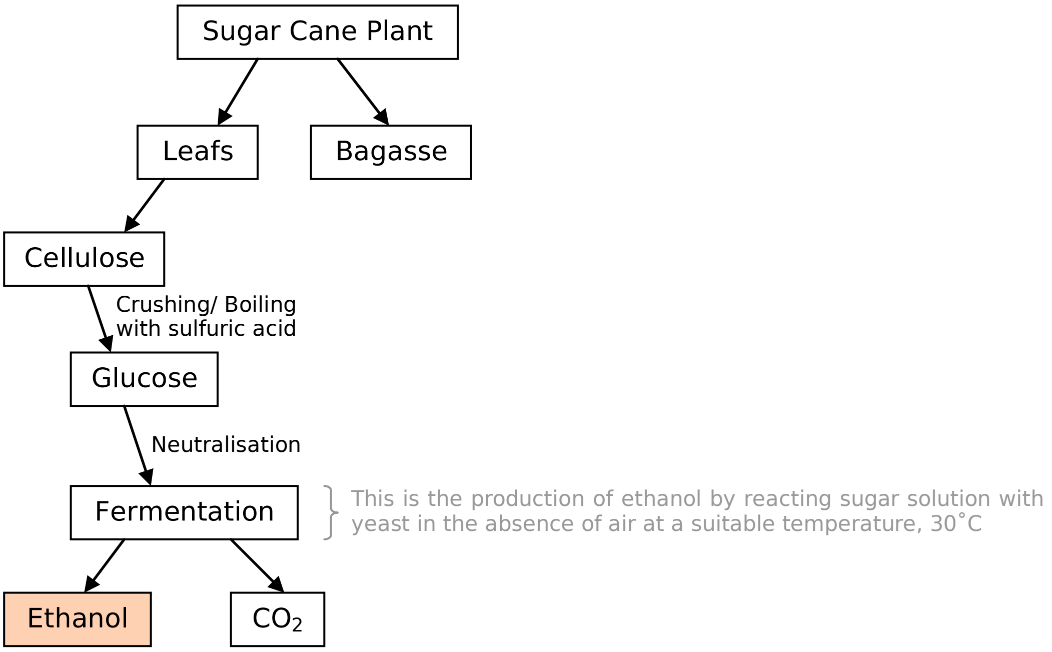


Fig. 31

The industrial production of ethanol from sugar cane plant is summarised in the flowchart above. Firstly the leafs are separated from the baggase. The baggase is considered waste. The leafs are mostly cellulose. The cellulose is then broken down into the smaller glucose by crushing and boiling with sulfuric acid. Glucose is then neutralised and then fermented. Ethanol is fractionally distilled from the fermentation mixture.

3. process information from secondary sources to summarise the use of ethanol as an alternative car fuel, evaluating the success of current usage

For ethanol to be used as a car fuel you need a lot of sugar cane plants, and that means lots of **land** to grow the sugar cane. Also the current solution, petrol, is currently **cheaper** and easier to produce than ethanol. However in the future the price of petrol may rise and ethanol will become a viable option.

4. solve problems, plan and perform a first-hand investigation to carry out the fermentation of glucose and monitor mass changes

Apparatus:

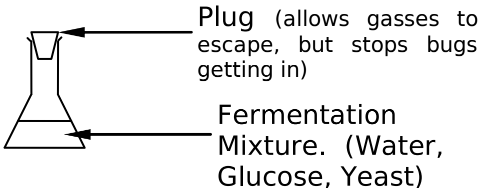


Fig. 32

Results:

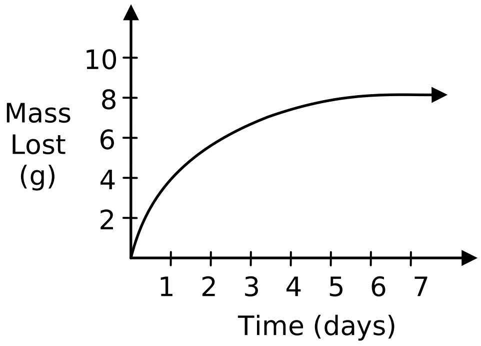


Fig. 33

Calculations:

$$C_6H_{12}O_6(aq) \xrightarrow{yeast} 2C_2H_5OH(aq) + 2CO_2(g)$$

1 mole 2 mole 2 mole

mass CO_2 produced = 11.25g

$$\text{moles} = \frac{\text{mass}}{\text{molar mass}} = \frac{11.25}{44.01} = 0.256\text{mol}$$

As the mole ratios of ethanol and carbon dioxide are both 2, if 0.256 moles of CO_2 is produced, 0.256 moles of C_2H_5OH is produced. So $n = \frac{m}{MM}$, $m = 0.256 \times (12.01 \times 2 + 1.008 \times 6 + 16.00) = 11.79\text{g}$.

Mass Glucose Used:
2 moles CO_2 = 1 mole glucose
0.256 moles CO_2 = 0.128 mole glucose

therefore mass of glucose = 0.128 × 180.156 = 23.060g

Conclusion:
The results are not reliable because water could have been evaporated, and this mass was calculated as CO_2 lost.

5. present information from secondary sources by writing a balanced equation for the fermentation of glucose to ethanol

Production of ethanol by fermentation:

$$C_6H_{12}O_6(aq) \xrightarrow{yeast} 2C_2H_5OH(aq) + 2CO_2(g)$$

glucose ethanol

6. identify data sources, choose resources and perform a first-hand investigation to determine and compare heats of combustion of at least three liquid alkanols per gram and per mole

Aim: To determine the molar heat of combustion for some alkanols.

Apparatus:

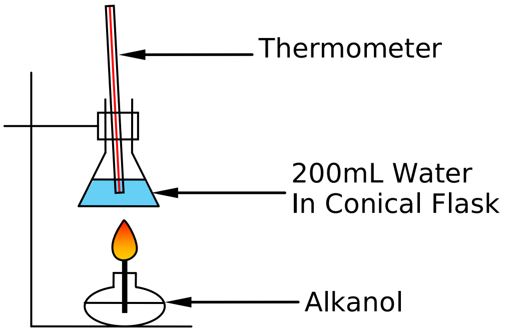


Fig. 34

Method:
A known volume of water is placed in a conical flask. The water in the conical flask is then heated via the spirit burner with the alkanol in it. The alkanols mass prior to combustion is weighed. Once the temperature of the water stops changing, the alkanol is re-weighted. Calculations are preformed on the recorded results.

Results:

No.	Alkanol	T_i (°C)	T_F (°C)	ΔT (°C)	M_i (g)	M_F (g)	ΔMass
1	Methanol	21	29	8	220.69	220.11	-0.58
2	Ethanol	21	29	8	187.87	187.39	-0.48
3	Propanol	21	29.5	8.5	224.58	224.17	-0.41

Calculations:

$$\Delta H = -mc\Delta T$$

$$\Delta H = -\underbrace{200\times10^{-3}}_{\text{mass of water}} \times \underbrace{4.18\times10^{3}}_{\text{sp. heat capacity of water}} \times \underbrace{8}_{\Delta T}$$

$\therefore\ \Delta H = -6688\text{J per } 0.58\text{g}$

As 1 mole of methanol equals 32.032g ($m = MM \times n$)

$$\frac{-6688}{0.58} = \frac{x}{32.032}$$

$x = -369\,362\ \text{J}$
$\therefore\ \Delta H = -369\ kJ\ mol^{-1}$

So the molar heat of combustion of methanol is 369kJ.

To calculate the heat of combustion per gram,
0.58g methanol gives a heat of combustion of -6688J, so 1 mole of ethanol gives a heat of combustion of z.

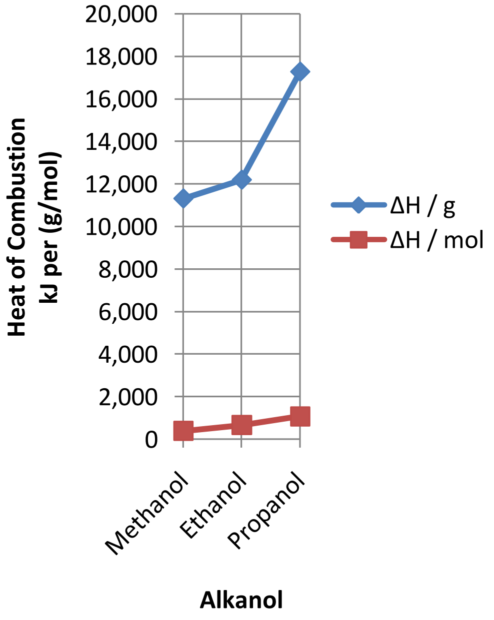
$$\frac{0.58}{-6688} = \frac{1}{z}$$

$$z = -11\,531\text{J}$$

The heat of combustion per gram of methanol is 11 531 J.

I should make a reference to topic 9.1 here as it seems quite relevant. In the formula $\Delta H = -mc\Delta T$, on the formula sheet c is given as $4.18 \times 10^3\ \text{J kg}^{-1}\ \text{K}^{-1}$. Now if we take this formula and make c the subject we get, $c = \frac{-\Delta H}{m\ \Delta T}$, and if we replace the quantities with their units as given be c, we get, $c = \frac{-\text{J}}{\text{kg K}}$. This means that if we want to use the c given on the formula sheet, then we need to ensure that m is in kg, and ΔH will be in J, and ΔT must be in K. However because K and $^\circ\text{C}$ are the same scale and because we are measureing ΔT and not T, the quantity will be the same in K or $^\circ\text{C}$.

Conclusion:



Alkanol	ΔH / g	ΔH / mol
Methanol	11 319	398
Ethanol	12 199	675
Propanol	17 278	1085

Sources of Error:
Heat was lost through air, the flask and evaporation of water. Also the mass of the spirit burner was inaccurate because the alkanols are volatile and evaporate quickly.

4. Oxidation-reduction reactions are increasingly important as a source of energy

1. explain the displacement of metals from solution in terms of transfer of electrons

Metals will displace metal ions when the metal is higher on the table of standard potentials. The metal reaction will be ← and the metal ion reaction will be →. From the full reaction we can see that the metal ions form solid which will deposit on the metal.

For example if we place zinc (Zn) metal in a copper sulfate ($CuSO_4$) solution, then the zinc will corrode and some copper will be deposited on the zinc metal, and the blue of the copper sulphate solution fades. This is a displacement reaction. The zinc has displaced the copper in the solution (Zn metal will displace Cu^{2+} ions as Zn is higher on the relativity reactivity series of metals, see next dot point). We can write two half equation for this reaction,

$$Zn \rightarrow Zn^{2+} + 2e^-$$
$$Cu^{2+} + 2e^- \rightarrow Cu$$

We can add these two reactions together to get the full reaction (the $2e^-$ cancel out),

$$Cu^{2+}{}_{(aq)} + Zn_{(s)} \rightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)}$$

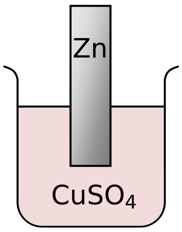
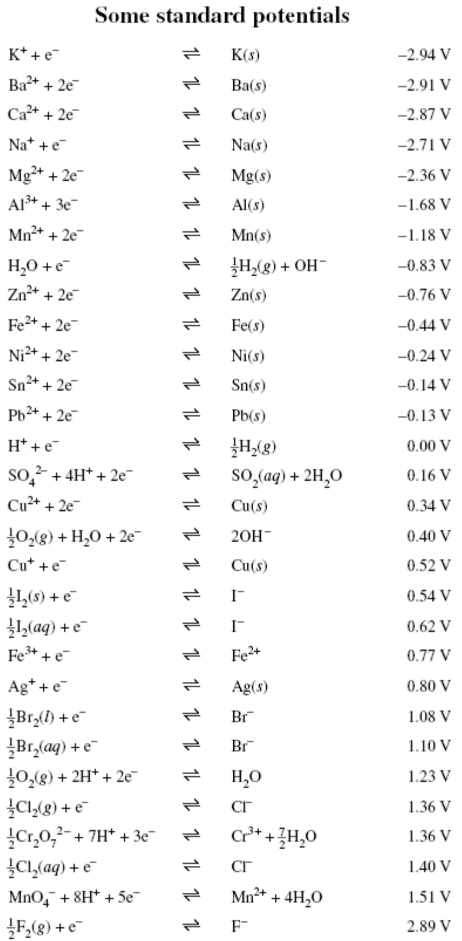


Fig. 35

From the half equations we see that Zn looses electrons and the Cu solution gains electrons.

2. identify the relationship between displacement of metal ions in solution by other metals to the relative activity of metals

The relative activity of metals can be found on the data sheet.



Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

On the left are the metal ions in solution, and on the right is the solid metal.

Reactions going → are called **Reduction**, because reduction is gain in electrons (OIL RIG).

Reactions going ← are called **Oxidation**, because oxidation is loss in electrons (OIL RIG).

A way to remember Reduction and Oxidation is with OIL RIG.

Oxidation	**R**eduction
Is	**I**s
Loss	**G**ain

Remember electrons are negatively charged.

The **more reactive** metal is the **anode**, which is **higher** on the standard potentials table. **Oxidation occurs at the anode**, **reduction occurs at the cathode**. (RED CAT, AN OX)

Metals higher on the relativity activity series of metals will displace ions which are lower. For example Zn metal will displace Cu^{2+} ions as Zn is higher than Cu^{2+}. However Cu metal will not displace Zn^{2+} ions as Zn is above Cu.

3. account for changes in the oxidation state of species in terms of their loss or gain of electrons

Oxidation states are used to determine if oxidation or reduction has occurred.

Group	Examples	Oxidation State
Uncombined Elements	Na, H_2	0
Ions	Na^+, S^{2-}	equal to their valance eg. $Na^+ = 1$, $S^{2-} = -2$
Oxygen in Compounds	CO_2	O = -2 (i.e. the valance of oxygen)
Hydrogen in Compounds	NaH H_2S	combined with metals -1 combined with non-metals +1

The total valency (charge) of the compound equals the sum of the oxidation states of the atoms.
Eg. The oxidation state of S in SO_3,
$S + O_3 = 0$ (zero due to zero overall charge)
$S + 3(-2) = 0$
$S = +6$ (the oxidation state of S in SO_3 is +6)

Oxidation involves an **increase** in oxidation state, from the uncombined element.
Reduction involves a **decrease** in oxidation state, from the uncombined element.

In the example above, as the uncombined element SO_3 has an oxidation state of 0, and the S has an oxidation state of +6, it has undergone oxidation.

4. describe and explain galvanic cells in terms of oxidation/reduction reactions

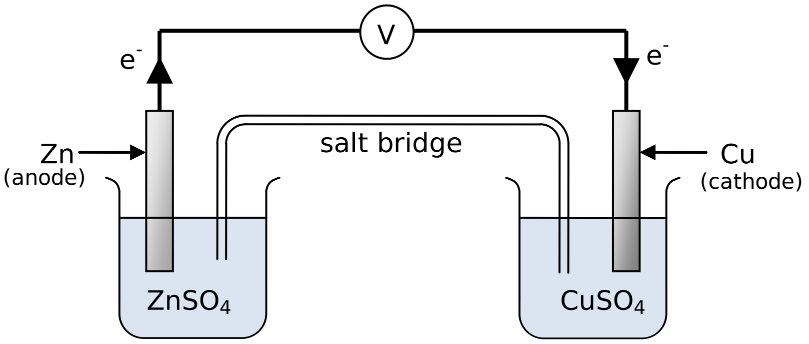
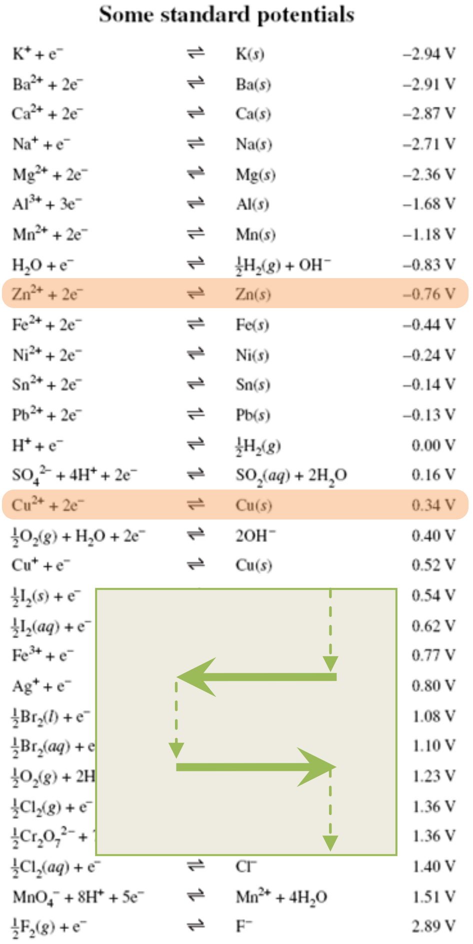


Fig. 36

- The **wire** that connects the two electrodes allows transfer of **electrons**.
- The **salt bridge** allows transfer of **ions**. (usually KNO_3)

To construct the oxidation/reduction reactions look at the table of standard potentials. Start from the top looking down the list until you find one of the two metals. Zinc is higher than Copper. The higher one we write ← and the lower one we write →.



Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$			0.54 V
$\frac{1}{2}I_2(aq) + e^-$			0.62 V
$Fe^{3+} + e^-$			0.77 V
$Ag^+ + e^-$			0.80 V
$\frac{1}{2}Br_2(l) + e^-$			1.08 V
$\frac{1}{2}Br_2(aq) + e$			1.10 V
$\frac{1}{2}O_2(g) + 2H$			1.23 V
$\frac{1}{2}Cl_2(g) + e^-$			1.36 V
$\frac{1}{2}Cr_2O_7^{2-} +$			1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Diagram adapted from NSW Board of Studies, Chemistry Some Standard Potentials

So the two half equations will be,

$$Zn \longrightarrow Zn^{2+} + 2e^-$$
$$Cu^{2+} + 2e^- \longrightarrow Cu$$

The first one is losing electrons so it is the oxidation half equation (OIL RIG). The second one is gaining electrons so it is the reduction half equation (OIL RIG).

Ox: $Zn \longrightarrow Zn^{2+} + 2e^-$
Red: $Cu^{2+} + 2e^- \longrightarrow Cu$

To get the full equation (redox reaction) these two half equations are added together.

$$Zn + Cu^{2+} + 2e^- \longrightarrow Zn^{2+} + 2e^- + Cu$$

The 2e⁻ on both sides cancels out to get,

$$Zn_{(s)} + Cu^{2+}{}_{(aq)} \longrightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)}$$

To find the voltage (potential difference) of this galvanic cell the voltages of the two half equations are added together.

When reading reaction on the table of standard potentials, the voltages is for reactions going → way, the voltage of reactions going ← way is the negative of the value shown.

$$\begin{array}{ll} Zn \longrightarrow Zn^{2+} + 2e^- & +0.76\text{ V} \\ \underline{Cu^{2+} + 2e^- \longrightarrow Cu} & \underline{+0.34\text{ V}} \\ Zn_{(s)} + Cu^{2+}{}_{(aq)} \longrightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)} & 0.34 + 0.76 = 1.1\text{V} \end{array}$$

Now if we look at the oxidation and reduction reactions we see that the Zinc metal is losing electrons, and the Cu^{2+}(aq) is gaining electrons to form Copper metal. From this we can say that the electrons are travelling from the Zn to Cu, so we can draw this on the diagram. We also know that oxidation occurs at the anode and that the anode is higher on the table of standard potentials, so the Zn metal is the anode and the Cu metal is the cathode. We may also notice a pile of Zn forming below the Zn metal, and the copper sulfate solution will become pale in colour.

5. outline the construction of galvanic cells and trace the direction of electron flow

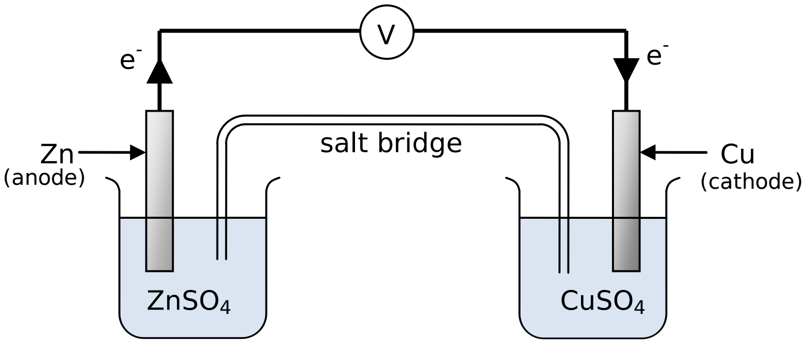


Fig. 37

A galvanic cell when two metals are placed in a solution of that metal in separate beakers. A wire connects the two metals (transfer of electrons) and a salt bridge connects the two solutions (transfer of ions). The salt bridge is made in the laboratory by soaking a paper in a salt solution.

The direction of electron flow can be determined by inspecting the oxidation and reduction reactions. The two half equations of the above cell are,

Ox: $Zn \longrightarrow Zn^{2+} + 2e^-$
Red: $Cu^{2+} + 2e^- \longrightarrow Cu$

The Zn metal is losing electrons and the Cu metal is gaining electrons. Therefore the electrons must go from Zn to Cu. The metal that undergoes oxidation is the anode and the metal that undergoes reduction is the cathode. (**Red**uction **Cat**hode **An**ode **Ox**idation, (RED CAT; AN OX))

6. define the terms anode, cathode, electrode and electrolyte to describe galvanic cells

The **electrodes** are the two pieces of **metal** partially placed in the solution. They are connected with a wire. The **electrolyte** is the **solution** in the beakers. The **anode** is the metal undergoing **oxidation**. The **cathode** is the metal undergoing **reduction**. (**Red**uction **Cat**hode **An**ode **Ox**idation)

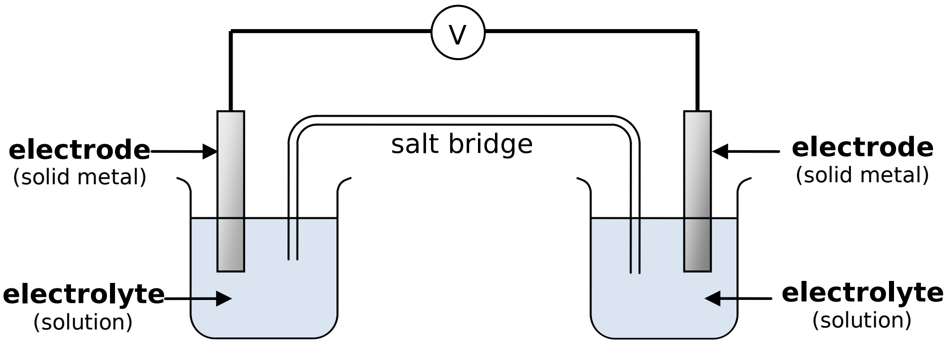


Fig. 38

1. perform a first-hand investigation to identify the conditions under which a galvanic cell is produced

2. perform a first-hand investigation and gather first-hand information to measure the difference in potential of different combinations of metals in an electrolyte solution

3. gather and present information on the structure and chemistry of a **dry cell** or **lead-acid cell** and evaluate it in comparison to one of the following:

- **button cell**
- fuel cell
- vanadium redox cell
- **lithium cell**
- liquid junction photovoltaic device (eg the Gratzel cell)

in terms of: ***(Dry Cell)***

- chemistry

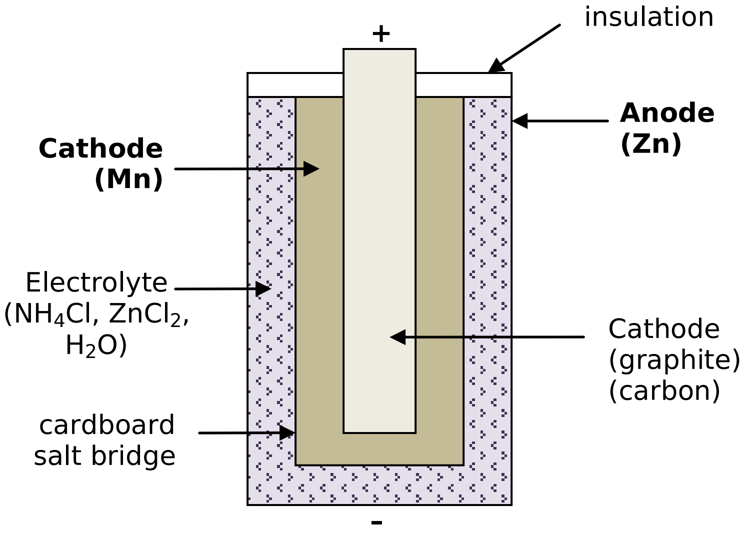


Fig. 39

Oxidation Reaction: $Zn(s) \longrightarrow Zn^{2+}(aq) + 2e^-$

Reduction Reaction: $Mn^{4+} + e^- \rightarrow Mn^{3+}$

Redox Reaction: $Zn(s) + Mn^{4+} \longrightarrow Zn^{2+}(aq) + Mn^{3+}$

- cost and practicality

- very **cheap** (40 cents)
- **readily available** (purchased from supermarkets).
- used in torches, TV remotes, portable CD players, alarm clocks, etc.
- However they have a **short life**.
- They **cannot be recharged**.
- They are big, bulky and heavy compared to the button cell, however quite small and light compared to the lead-acid battery.

- impact on society

As they are relatively small and light, they can are used to make **portable appliances**. For example, a portable radio, can impact society as it can be used to inform people on boats of approaching storms. This warning can save them from the storm.

- environmental impact

If used continuously, ammonia produced may expand and cause the cell to burst. This ammonia can be dangerous to the environment if it ends up in waterways. Also as these batteries are non-rechargeable and as they don't last long, many end up in **landfill**.

in terms of: ***(Lead-Acid Cell)***

- chemistry

Cathode: Lead Oxide (PbO_2)
Anode: Lead metal (Pb)
Electrolyte: Concentrated Sulfuric Acid (H_2SO_4)

Oxidation Reaction: $Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^-$

Reduction Reaction: $PbO_2(s) + 4H^+(aq) + 2e^- \rightarrow Pb^{2+}(aq) + 2H_2O(l)$

- cost and practicality

- Used as car batteries
- **Can be recharged**.
- They are **big, bulky and heavy**.
- Can deliver **large voltages**.

- impact on society

Allows people to run electronic devices in cars which allows people to survive in the outback longer.

- environmental impact

Lead is toxic and sulfuric acid is dangerous. The battery cannot be recycled and pose a large environmental if disposed in landfill. They must be disposed of properly.

in terms of: ***(Lithium Cell) (aka. Lithium ion cell)***

- chemistry

Cathode: Lithium (Li)
Anode: Iodine (I_2)
Electrolyte: Lithium Iodide

Oxidation Reaction: $Li(s) \longrightarrow Li^+(aq) + e^-$

Reduction Reaction: $I_2(g) + e^- \rightarrow 2I^-(aq)$

- cost and practicality

- Used in mobile phones.
- **Can be recharged**.
- **Long Lasting**
- **Light weight**
- Produce a **high voltage**
- Quite **expensive**

- impact on society

Allows people to run electronic devices in cars which allows people to survive in the outback longer.

- environmental impact

in terms of: ***(Button Cell)***

- chemistry

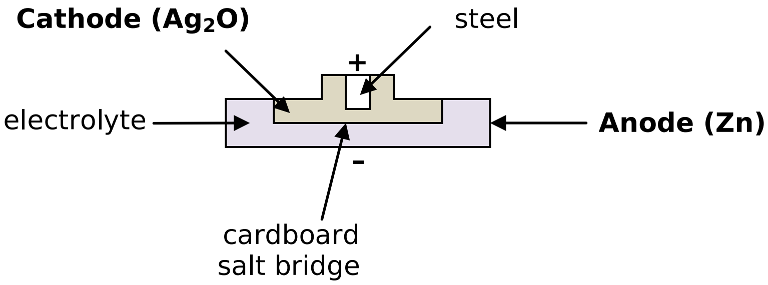


Fig. 40

Oxidation Reaction: $Zn(s) \longrightarrow Zn^{2+} + 2e^-$

Reduction Reaction: $Ag^+ + e^- \longrightarrow Ag(s)$

Redox Reaction: $Zn(s) + 2Ag^+ \longrightarrow Zn^{2+} + 2Ag(s)$

- cost and practicality

- The button cell is slightly more expensive than the dry cell, however it is still relatively **cheap**, with a rough price of about $2-$4.
- Slightly less available than the dry cell but can be found in some supermarkets and most electronics stores.
- Used in items such as **watches**, **pocket calculators** and a range of other small electronic devices.
- They are **very small** and **very light** and easy to use.
- They are **not rechargeable**.

- impact on society

As the button cell is very small and light, it has allowed small electronic devices to be keep to minimal sizes. Along with the fact that they are light weight, they have allowed these tiny electronic devices to operate and to be so small and portable. Eg. **Their use in pacemakers has allowed people to live longer**.

- environmental impact

When the battery is exhausted and thrown away the **heavy metals** in the cell, which are **toxic**, are released into the environment where the battery was disposed. This can pollute waterways and harm people who come in contact with it.

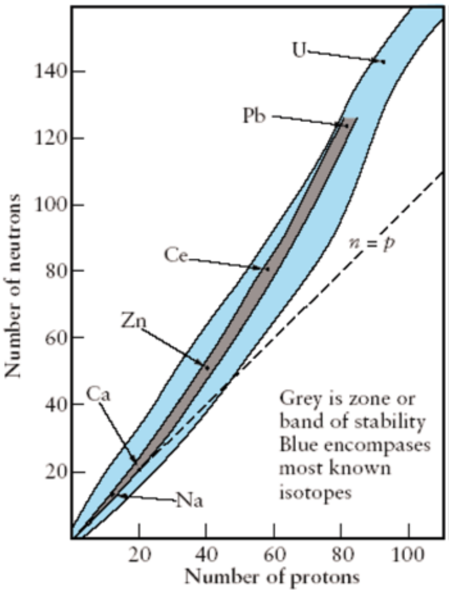
4. solve problems and analyse information to calculate the potential E^{θ} requirement of named electrochemical processes using tables of standard potentials and half-equations

It should also be noted why experimental values may differ from those on the table of standard potentials. These standard potentials are measured under standard conditions of **25°C**, **100kPa** and using **1 mol L^{-1}** solution. A change in these conditions results in a change in the value of E^{Θ}.

5. Nuclear chemistry provides a range of materials

1. distinguish between stable and radioactive isotopes and describe the conditions under which a nucleus is unstable

Radioactive isotopes are isotopes which emit alpha, beta or gamma radiation. An isotope is a form of an element, thus has the same number of protons and electrons, but has a different mass number, thus a different number of neutrons. Radioactive isotopes occur when either the size of the nucleus or when the ratio of protons to neutrons if too high.



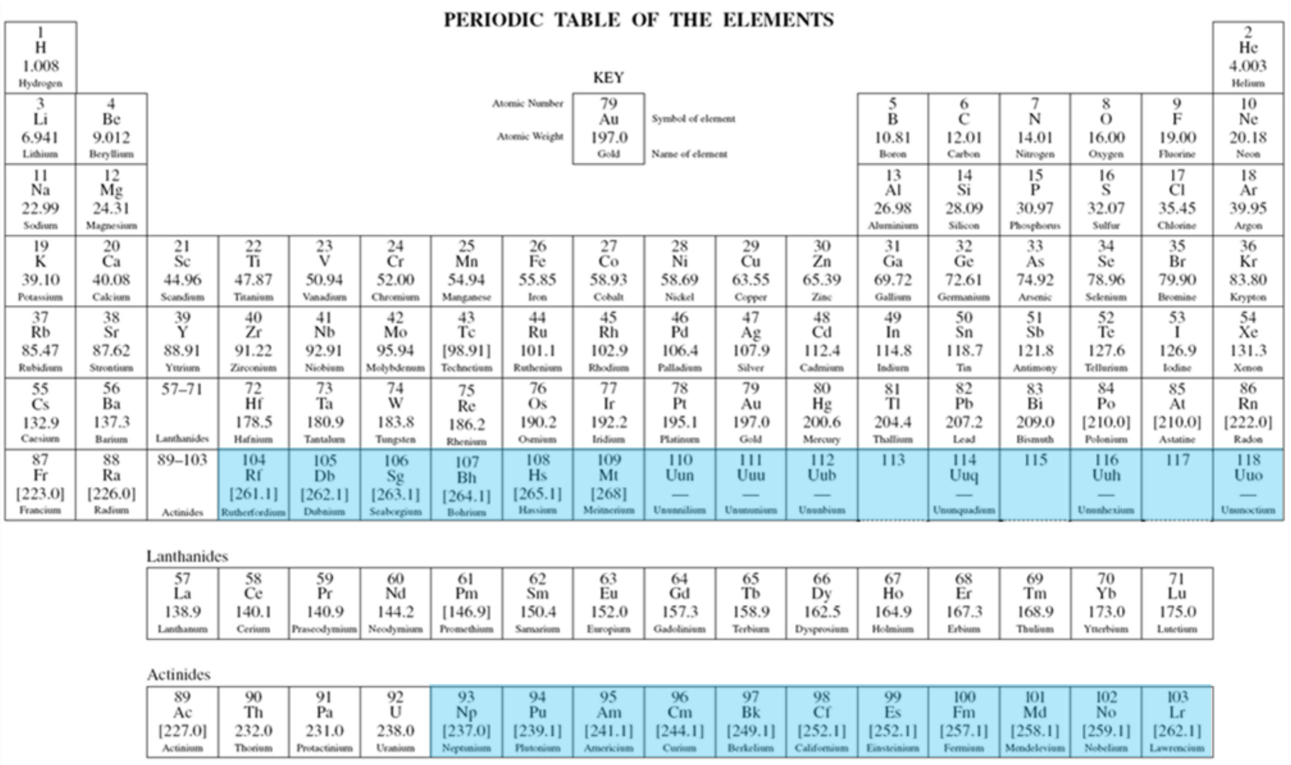
Grey is zone or band of stability Blue encompasses most known isotopes

R. Smith, Conquering Chemistry, p69

Fig. 41

2. describe how transuranic elements are produced

Transuranic elements (aka. transuranics) are elements that come after element 92 (Uranium) on the periodic table. These elements are not found in nature and are made in the laboratory, in nuclear reactors. Protons are shot into the nucleus of atoms, this increases the atomic number and changes the element. All transuranic elements are radioactive isotopes.



PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number — 79
Symbol of element — Au
Atomic Weight — 197.0
Name of element — Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Ununbium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [146.9] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinides

89 Ac [227.0] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237.0] Neptunium	94 Pu [239.1] Plutonium	95 Am [241.1] Americium	96 Cm [244.1] Curium	97 Bk [249.1] Berkelium	98 Cf [252.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium

Diagram adapted from NSW Board of Studies, Chemistry Periodic Table of Elements

Fig. 42

3. describe how commercial radioisotopes are produced

Radioactive isotopes are either produced in a particle accelerator (e.g. cyclotron) by firing charged particles (eg. protons or small nuclei) at high speeds at nuclei, producing a nuclear reaction that creates a radioisotope, or they are produced in a nuclear reactor, where neutrons are bombarded into nuclei. This changes the number or protons or neutrons in the nucleus, thus making it a radioactive.

4. identify instruments and processes that can be used to detect radiation

- **Geiger-Muller tube** – It works through a sealed tube which contains argon gas. When radiation enters the tube it ionises the gas and this creates an electric signal. This is converted into sound and amplified and this allows you to hear a tone when a particle is detected.
- **Photographic film** – Where radiation will expose the film/paper.
- **Electroscope** – Detects ionising alpha particles in the air. As gamma rays have poor ionising ability this device does not recognise the gamma rays.

5. identify one use of a named radioisotope:

- in industry

Am-241 is used in **fire alarms**.

- in medicine

Tc-99m is used as a tracer to diagnose diseases by **showing** up **cancerous growths**.

6. describe the way in which the above named industrial and medical radioisotopes are used and explain their use in terms of their chemical properties

Tc-99m (Metastable Technetium-99) is a radio-isotope used in medicine as a tracer to detect abnormal cell growths (ie. cancer) and blood flow abnormalities. It is injected into the patient’s blood stream and is observed by the gamma radiation that it emits.

$$^{99m}_{43}Tc \rightarrow {}^{99}_{43}Tc + \gamma$$

Tc-99m is used because it:

- has a short half life of 6 hours
- is easily excreted
- emits low-energy gamma radiation
- shows blood flow abnormalities
- is easily attached to biological carriers

Americium-241 is used in smoke detectors, which are used industrially as a safety measures in factories. Fire Alarms contain Am-241 which radioactively decays producing alpha particles.

$$^{241}_{95}Am \rightarrow {}^{237}_{93}Np + {}^{4}_{2}He$$

When no smoke is present, the alpha particles ($^{4}_{2}He$) emitted from the Am ionise nitrogen and oxygen in the air in the detector. However when smoke is present, it absorbs the alpha particles so the rate of ionisation drops and this sets off the alarm.

1. process information from secondary sources to describe recent discoveries of elements

In nuclear reactors protons are fired at high speeds at atoms to change the structure, and thus make new elements.

2. use available evidence to analyse benefits and problems associated with the use of radioactive isotopes in identified industries and medicine

The benefits of radioactive isotopes in medicine include the ability to diagnose and treat things such as cancer. Benefits in industry include the ability to examine civil structures for possible problems in the materials, and also the ability to detect fires by the use of smoke alarms. The main problem with the use of radioactive isotopes is that expose to radiation can cause cancer.

In all these cases the use of radioactive isotopes either prevents or helps minimise or avoid potential injury or death to humans.

9.3 THE ACIDIC ENVIRONMENT

Contextual Outline:

Acidic and basic environments exist everywhere. The human body has a slightly acidic skin surface to assist in disease control and digestion occurs in both acidic and basic environments to assist the breakdown of the biopolymers constituting food. Indeed, microorganisms found in the digestive system are well adapted to acidic or basic environments.

Many industries use acidic and basic compounds for a wide range of purposes and these compounds are found in daily use within the home. Because of this, an awareness of the properties of acids and bases is important for safe handling of materials. Currently, concerns exist about the increased release of acidic and basic substances into the environment and the impact of these substances on the environment and the organisms within those environments.

This module increases students' understanding of the history, nature and practice of chemistry, the applications and uses of chemistry and implications of chemistry for society and the environment.

X

1. Indicators were identified with the observation that the colour of some flowers depends on soil composition

1. classify common substances as acidic, basic or neutral

MOST

LEAST

Acidic	Basic	Neutral
Vinegar HCl Coke-a-cola Stomach acid Lemon juice Wine Rain water Milk	Oven cleaner Bleach Detergent Soap Toothpaste Baking Soda Sea Water	Distilled Water

2. identify that indicators such as litmus, phenolphthalein, methyl orange and bromothymol blue can be used to determine the acidic or basic nature of a material over a range, and that the range is identified by change in indicator colour

Indicators such as litmus, phenolphthalein, methyl orange and bromothymol blue can be used to determine the acidic or basic nature of a material over a range, and the range is identified by change in indicator colour.

3. identify and describe some everyday uses of indicators including the testing of soil acidity/basicity

- Testing water acidity/basicity
- Testing soil acidity/basicity

1. perform a first-hand investigation to prepare and test a natural indicator

Red cabbage is a natural indicator. To make the indicator effective the liquid is extracted by crushing and grinding the cabbage to get the juice. Then different pH acids and bases can be placed in the cabbage juice and the colour will change depending upon the pH.

2. identify data and choose resources to gather information about the colour changes of a range of indicators[1]

Indicator	Colour in acid	Colour in base
Litmus	**Red**	**Blue**
Phenophalein	**Colourless**	**Red**
Methyl orange	**Pink**	**Yellow**
Bromothymol blue	**Yellow**	**Blue**

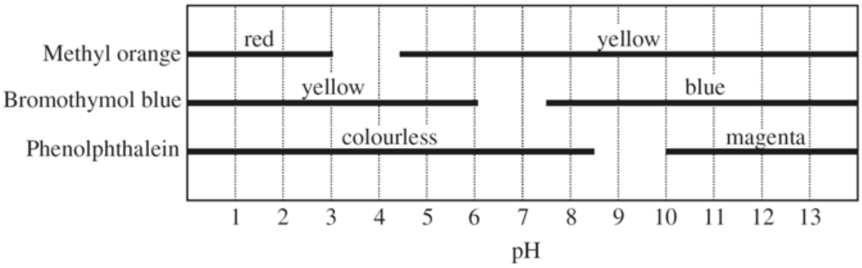


Fig. 43

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[1] I wish that I could say that you don't need to remember these, but unfortunately I cannot, sometimes in the HSC they give you the graph, but sometimes they don't.

3. solve problems by applying information about the colour changes of indicators to classify some household substances as acidic, neutral or basic

For example if you placed phenophalein in oven cleaner, the indicator would turn red. This indicates that oven cleaner is basic.

2. While we usually think of the air around us as neutral, the atmosphere naturally contains acidic oxides of carbon, nitrogen and sulfur. The concentrations of these acidic oxides have been increasing since the Industrial Revolution

1. identify oxides of non-metals which act as acids and describe the conditions under which they act as acids

The oxides of non-metal, excluding the noble gasses, act as acids. The conditions include under which they act as acids include that they must be **dissolved in water**. For example, the oxide of the non metal sulfur, when dissolved in water produces sulfurous acid,

$$SO_2 + H_2O \rightarrow H_2SO_3$$
$$H_2SO_{3(aq)} \rightleftharpoons 2H^+ + SO_3^{2-}$$

2. analyse the position of these nonmetals in the Periodic Table and outline the relationship between position of elements in the Periodic Table and acidity/basicity of oxides

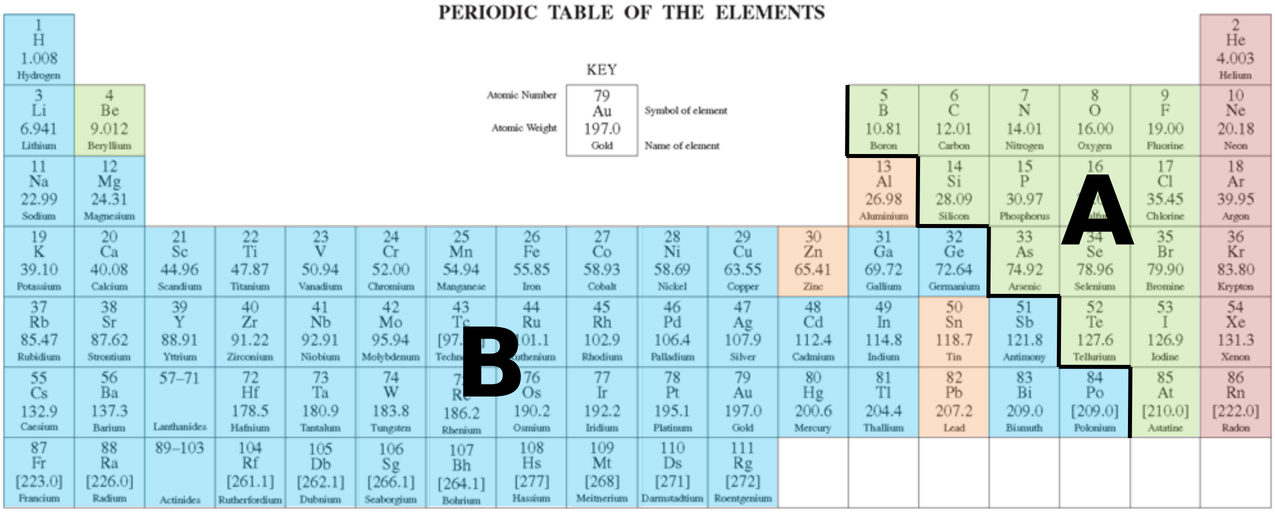


Fig. 44

Diagram adapted from NSW Board of Studies, Chemistry Periodic Table of Elements

🟦 Dissolved oxides are **basic**

🟩 Dissolved oxides are **acidic**

🟥 No oxides

🟧 Dissolved oxides are **amphoteric**

3. define Le Chatelier’s principle

If any chemical system in equilibrium is subjected to a change in pressure, volume, concentration or temperature, then the system will react in the direction to **minimise the effect of the change**.

4. identify factors which can affect the equilibrium in a reversible reaction

- Temperature
- Concentration
- Pressure
- Volume

(See section 2 of the option Industrial Chemistry for a more detailed summary.)

5. describe the solubility of carbon dioxide in water under various conditions as an equilibrium process and explain in terms of Le Chatelier’s principle

The equilibrium between gaseous CO_2 and CO_2 dissolved in water is best considered using two reactions.

$$CO_{2(g)} \rightleftharpoons CO_{2(aq)} + heat$$

$$CO_{2(aq)} + H_2O \rightleftharpoons H_2CO_{3(aq)}$$

If heat is increased, the equilibrium moves left (of the first equation) to reduce the heat, so there is more CO_2 in gas form.

If pressure is increased, the equilibrium moves to the side with the least moles to release the pressure, which is to the right so that more H_2CO_3 is formed and more CO_2 gas is dissolved to make up for the lost CO_2 aqueous.

Hence CO_2 is soluble in water at low temperatures and high pressures.

6. identify natural and industrial sources of sulfur dioxide and oxides of nitrogen

	Natural Sources	Industrial Sources
SO_2	**Decomposition of organic matter**	**Combustion of fossil fuels**
NO_X	**Lightning** **Volcanoes**	**Combustion of fuels**

7. describe, using equations, examples of chemical reactions which release sulfur dioxide and chemical reactions which release oxides of nitrogen

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

$$N_{2(g)} + 2O_{2(g)} \xrightarrow{heat} 2NO_{2(g)}$$

The oxides of nitrogen NO_X include, nitrogen monoxide NO, nitrogen dioxide NO_2, etc.

8. assess the evidence which indicates increases in atmospheric concentration of oxides of sulphur and nitrogen

The evidence comes from,

- Ice core samples
- Weathering of statues

9. calculate volumes of gases given masses of some substances in reactions, and calculate masses of substances given gaseous volumes, in reactions involving gases at 0˚C and 100kPa or 25˚C and 100kPa

The volume of gasses can be calculated using moles and the data sheet. 1 mole of an ideal gas at 100kPa at 0℃ is 22.71L and at 25℃ is 24.79L. See blue dot point 1.

10. explain the formation and effects of acid rain

Due to pollution of the air, the air contains toxic gasses such as sulfur dioxide (SO_2), carbon dioxide (CO_2) and nitrogen dioxide (NO_2). These toxic gasses are removed by the air via rain, where slight acidic water is formed, known as acid rain.

$$\underset{\text{sulfur dioxide}}{\mathrm{SO}_{2(g)}} + \mathrm{H_2O}_{(l)} \leftrightharpoons \underset{\text{sulfurous acid}}{\mathrm{H_2SO}_{3(aq)}}$$

We know that $\mathrm{H_2SO}_{3(aq)}$ is acidic as it ionises in water given by, $\mathrm{H_2SO}_{3(aq)} \rightleftharpoons \mathrm{H}^+ + \mathrm{HSO}_3^-$, which is acidic due to the excess H^+ ions.

Sulfur trioxide can also form in the atmosphere,

$$2\mathrm{SO}_2(g) + \mathrm{O}_2(g) \rightarrow 2\mathrm{SO}_3(g)$$

This then reacts with water to form sulfuric acid, or acid rain,

$$\mathrm{SO}_3(g) + \mathrm{H_2O}(l) \rightarrow \mathrm{H_2SO_4}(aq)$$

$$\mathrm{H_2SO_4}(aq) \rightleftharpoons \mathrm{2H^+ + SO_4^-}$$

Acid rain can also form from carbon dioxide or nitrogen dioxide,

$$\mathrm{CO_2}(g) + \mathrm{H_2O}(l) \rightarrow \underset{\text{carbonic acid}}{\mathrm{H_2CO_3}(aq)}$$

$$\mathrm{4NO_2}(g) + \mathrm{2H_2O}(l) + \mathrm{O_2}(g) \rightarrow \underset{\text{nitric acid}}{\mathrm{4HNO_3}(aq)}$$

The affects of acid rain include:
- **Corrosion** and decay of buildings and stone structures
- **Plant life** may be stunted or destroyed, as the soil becomes too acidic
- **Rivers** and lakes become too acidic and the marine life suffers

1. identify data, plan and perform a first-hand investigation to decarbonate soft drink and gather data to measure the mass changes involved and calculate the volume of gas released at 25˚C and 100kPa

Soda water consists of CO_2 gas and H_2O in solution. H_2O boils at 100℃, and CO_2 boils at a much lower temperature. So to calculate the amount of CO_2 gas in the soda water, first weight the mass of the soda water, then heat the solution, but keeping it well below 100℃ (to avoid evaporation water), once the bubbles stop rising (this means all the CO_2 is gone) weigh the mass of the remaining soda water. The mass decreases as CO_2 gas has escaped. Using the mass of the original soda water and the mass of the CO_2 lost, the concentration of CO_2 in soda water (v/v) can be calculated.

Example data:
Mass of soda water = 108.20g
Mass of CO_2 = 2.77g
Volume of soda water = 108.20 mL
Volume CO_2 at 25℃ = $\frac{\mathrm{mass\ \ CO_2}}{\mathrm{molar\ \ mass\ \ CO_2}} = \frac{2.77}{44.01} \times 24.79 = 1.56\mathrm{L}$
1.56L CO_2 per 0.10802L soda water
*x*L CO_2 per 1L soda water
$\frac{1.56}{0.10802} = 14.4\mathrm{L}$

Every 1L of soda water contains 14.4L CO_2

See 9.1 H11.2.b, page 5 for a note about the use of controls in this experiment.

2. analyse information from secondary sources to summarise the industrial origins of sulphur dioxide and oxides of nitrogen and evaluate reasons for concern about their release into the environment

An industrial source of the oxides of nitrogen is the combustion of fuels. An industrial source of sulfur dioxide is the combustion of fossil fuels. The release of the oxides of nitrogen and sulfur dioxide into the atmosphere is a concern because they cause acid rain .

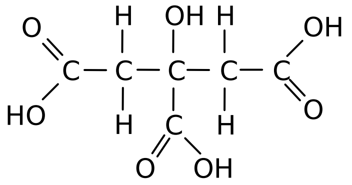
3. Acids occur in many foods, drinks and even within our stomachs

1. define acids as proton donors and describe the ionisation of acids in water

An acid is a substance that can donate one or more protons (hydrogen ions, because a hydrogen atom that has lost an electron only has the nucleus which is made up of solely one proton). Acids ionise (i.e. the molecule breaks down forming ions) in water to produce hydrogen ions, H^+.

$$\underset{\text{hydrochloric acid}}{HCl_{(aq)}} \rightarrow \underset{\text{hydrogen ion}}{H^+{}_{(aq)}} + \underset{\text{chloride ion}}{Cl^-{}_{(aq)}}$$

2. identify acids including acetic (ethanoic), citric (2-hydroxypropane-1,2,3-tricarboxylic), hydrochloric and sulfuric acid

Strong Acid (Ionises completely in H_2O)	Weak Acid (Ionises partially in H_2O)
Hydrochloric acid (HCl) $\boldsymbol{HCl_{(aq)} \leftrightharpoons H^+{}_{(aq)} + Cl^-{}_{(aq)}}$ **Sulfuric acid (H_2SO_4)** $\boldsymbol{H_2SO_4{}_{(aq)} \leftrightharpoons 2H^+{}_{(aq)} + SO_4^{2-}{}_{(aq)}}$	**Acetic (ethanoic) acid (CH_3COOH)**, is a main component of vinegar. $CH_3COOH_{(aq)} \leftrightharpoons CH_3COO^-{}_{(aq)} + H^+{}_{(aq)}$ **Citric acid** (2-hydroxypropane-1,2,3-tricarboxylic), is the acid found in citrus fruits.  citric acid (2-hydroxypropane-1,2,3-tricarboxylic acid)

3. describe the use of the pH scale in comparing acids and bases

pH	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
$[H^+]$	10^0	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}	10^{-12}	10^{-13}	10^{-14}

most acidic (strong acid)

(weak acid)

neutral

(weak base)

most basic (strong base)

The pH scale is a logarithmic scale of acidity/basicity. It is a measure of hydrogen ion concentration, $\mathrm{pH} = -\log_{10}[H^+]$.

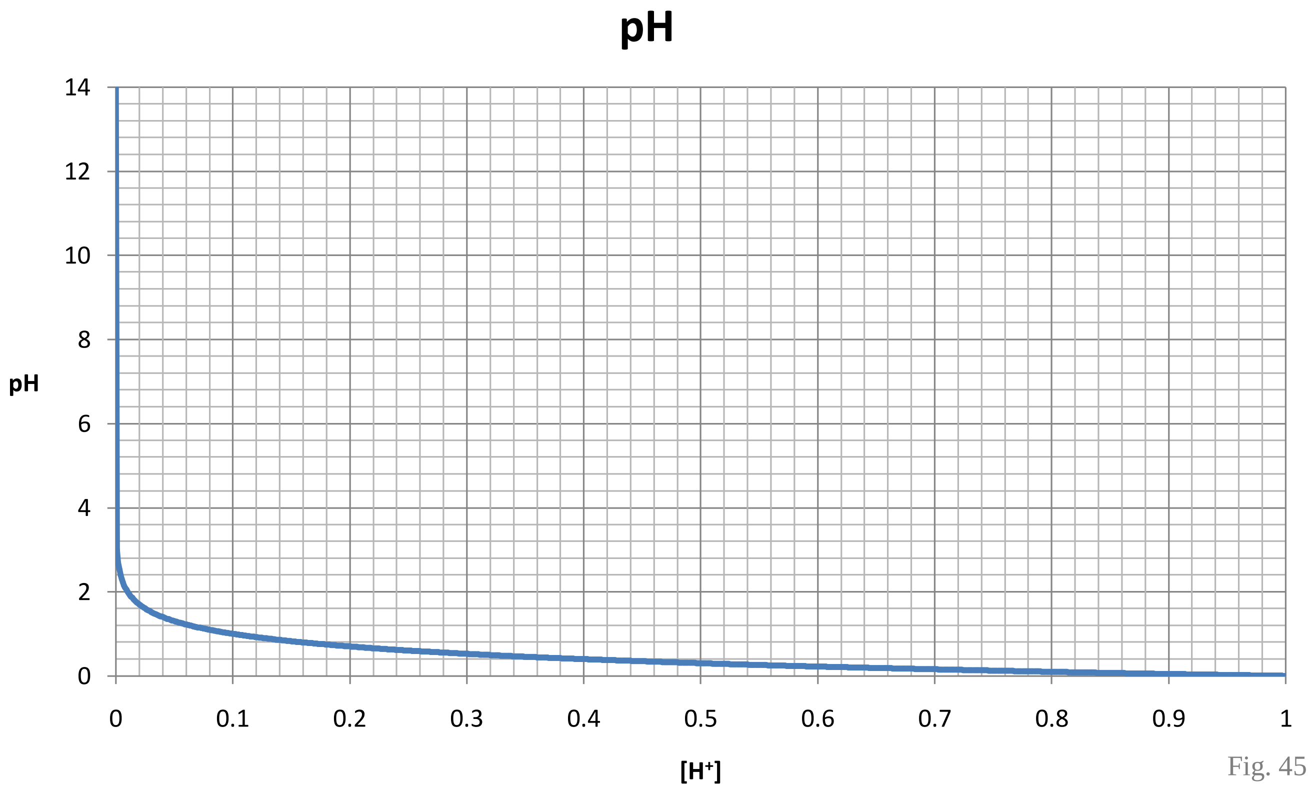


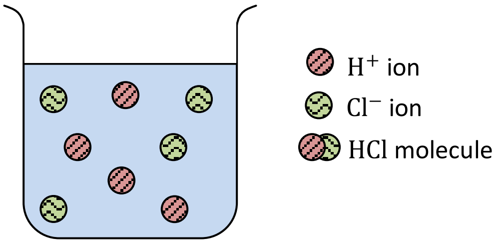
Fig. 45

4. describe acids and their solutions with the appropriate use of the terms strong, weak, concentrated and dilute

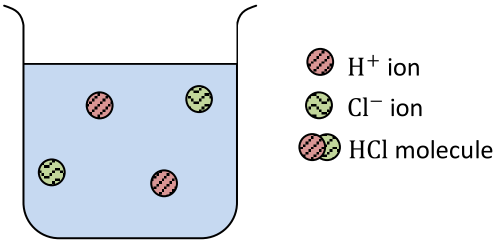
A strong acid is one that ionises completely in solution, donating protons freely. eg. HCl, H_2SO_4
A weak acid is one that does not ionise completely in solution. eg. H_2CO_3, CH_3COOH

The strength of an acid is determined by its ionising ability, the strength does not change depending on its concentration. The concentration of an acid, or anything for that matter, is just how many molecules per some unit volume, $c = \frac{n}{v}$.

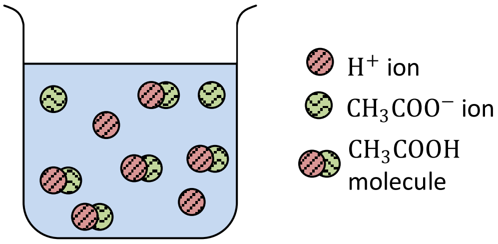
HCl = strong acid
5 mol/L = concentrated solution



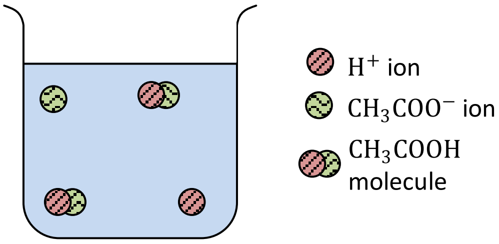
HCl = strong acid
0.5 mol/L = dilute solution



CH_3COOH = weak acid
5 mol/L = concentrated solution



CH_3COOH = weak acid
0.5 mol/L = dilute solution



As seen from the diagrams above, strong and weak acids are not the same as concentrated and dilute solutions. A strong acid has almost no molecules, it is almost all ionised. The concentrated/dilute solution of the strong acid just changes how many total molecules/ions present, not the ratio of molecules to ions. A weak acid, has many molecules and a few ions. However the ratio of molecules to ions does not vary depending on the concentration.

5. identify pH as $-\log_{10}$ $[H^+]$ and explain that a change in pH of 1 means a ten-fold change in $[H^+]$

$$\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$$

where, $[H^+]$ = hydrogen ion concentration

As this is a log function if the pH changes by 1 then the $[H^+]$ changes by a rate of 10.
pH 0 = 1 $[H^+]$
pH 1 = 0.1 $[H^+]$
pH 2 = 0.01 $[H^+]$
As you can see a double in pH does not result in a double in $[H^+]$.

6. compare the relative strengths of equal concentrations of citric, acetic and hydrochloric acids and explain in terms of the degree of ionisation of their molecules

Acid	Concentration	pH	Strength	Degree of Ionisation
Citric	0.1M	2.1	Weak	8%
Acetic	0.1M	2.9	Weak	1.3%
Hydrochloric	0.1M	1	Strong	100%

The degree of ionisation determines whether it is a strong or weak acid.

7. describe the difference between a strong and a weak acid in terms of an equilibrium between the intact molecule and its ions

We can describe the differences between strong and weak acids in terms of the equilibrium between its molecules and ions.

$$\underbrace{\mathrm{HCl}(aq)}_{\text{intact molecule}} \leftrightharpoons \underbrace{\mathrm{H}^+(aq) + \mathrm{Cl}^-(aq)}_{\text{ions}}$$

The equilibrium of the above equation lies very much to the right, as it ionises completely, making it a strong acid and resulting in only ions and no intact molecules.

$$\mathrm{CH_3COOH}(aq) \leftrightharpoons \mathrm{CH_3COO^-}(aq) + \mathrm{H}^+(aq)$$

However for the reaction shown above, the equilibrium lies much to the left because it is a weak acid and most of the molecules do not ionise and remain intact molecules.

1. solve problems and perform a first-hand investigation to use pH meters/probes and indicators to distinguish between acidic, basic and neutral chemicals

A pH meter/probe is an electronic device that measures pH. pH metres/probes are much more accurate than indicators, where a pH metre has about **0.01 accuracy** and indicator at best has 1pH accuracy. Also the pH meter is **not affected by the colour of the original substance**, unlike indicators which are. However the pH meter must be **calibrated and rinsed in water** to neutralise it before use.

2. plan and perform a first-hand investigation to measure the pH of identical concentrations of strong and weak acids

Acid	Concentration	pH	Strength	Degree of Ionisation
Citric	0.1M	2.1	Weak	8%
Acetic	0.1M	2.9	Weak	1.3%
Hydrochloric	0.1M	1	Strong	100%

3. gather and process information from secondary sources to write ionic equations to represent the ionisation of acids

$$\mathrm{HCl}(aq) \leftrightharpoons \mathrm{H}^+(aq) + \mathrm{Cl}^-(aq)$$

$$\mathrm{CH_3COOH}(aq) \leftrightharpoons \mathrm{CH_3COO}^-(aq) + \mathrm{H}^+(aq)$$

4. use available evidence to model the molecular nature of acids and simulate the ionisation of strong and weak acids

5. gather and process information from secondary sources to explain the use of acids as food additives

Acids are used as food additives. They are used because they have a low pH and this kills microorganisms, eg. bacteria. They are also used to improve the taste.

6. identify data, gather and process information from secondary sources to identify examples of naturally occurring acids and bases and their chemical composition

- Citric acid (CH_3COOH) is the acid found in citrus fruits.
- Hydrochloric acid (HCl) is naturally found in the stomach.
- Ammonia (NH_3) is a naturally occurring base found in urine.
- Carbonates (XCO_3) are also found in shells and coral. They are basic.

7. process information from secondary sources to calculate pH of strong acids given appropriate hydrogen ion concentrations

$\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$

It should be noted that when you have substances that ionise to form H^+, where the H^+ has a mole ratio not equal to 1, then you need to multiply that mole ratio by the hydrogen ion concentration given.

4. Because of the prevalence and importance of acids, they have been used and studied for hundreds of years. Over time, the definitions of acid and base have been refined

1. outline the historical development of ideas about acids including those of:

- Lavoisier

Lavoisier hypothesised that all acids contained oxygen.

- Davy

Davy showed that HCl did not contain oxygen, he proposed that all acids contained hydrogen not oxygen.

- Arrhenius

Arrhenius proposed that an acid is a substance which produces hydrogen ions in water. This meant that an acid is a substance that ionises in water to produce hydrogen ions (H^+) as the only positive ions. A base is a substance that ionises in water to produce hydroxide ions (OH^-) as the only negative ions.

2. outline the Brönsted-Lowry theory of acids and bases

Brönsted-Lowry theory states that an **acid** is a substance that **donates a proton** (hydrogen ion) to a base, and a **base** is a substance **that accepts a proton** from an acid. According to the theory an acid/base reaction is one in which a proton is transferred from an acid to a base.

In the Brönsted-Lowry theory of acids and bases the ionisation of HCl is represented by the equation, (which is also represented on the molecular level below)

$$\mathrm{HCl}(g) + \mathrm{H_2O}(l) \rightleftharpoons \mathrm{H_3O^+}(aq) + \mathrm{Cl^-}(aq)$$

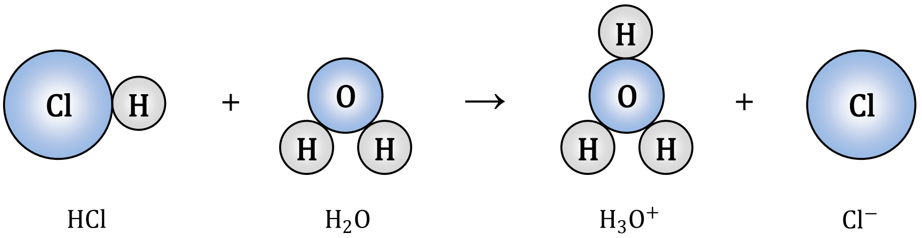


Fig. 46

You will see that the HCl has donated a proton to the $\mathrm{H_2O}$. This means that the HCl is acting as an acid and the $\mathrm{H_2O}$ is acting as a base.

We can also consider the reaction when ammonia dissolves in water, shown below.

$$\mathrm{NH_3}(aq) + \mathrm{H_2O}(l) \rightleftharpoons \mathrm{NH_4^+}(aq) + \mathrm{OH^-}(aq)$$

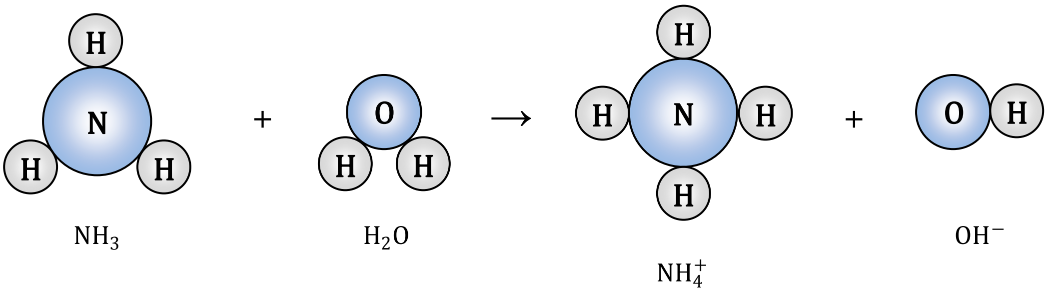


Fig. 47

As you can see the $\mathrm{NH_3}$ has accepted a proton from the $\mathrm{H_2O}$. Thus the $\mathrm{NH_3}$ is acting as a base and the $\mathrm{H_2O}$ is acting as an acid.

3. describe the relationship between an acid and its conjugate base and a base and its conjugate acid

An acid gives up a proton to form its conjugate base.

$$\begin{gathered}\mathrm{HX} \rightarrow \mathrm{H}^+ + \mathrm{X}^- \\ \text{acid} \rightarrow \text{proton} + \text{conjugate base}\end{gathered}$$

For example,

$$\underset{\text{acid}}{\mathrm{H_3O^+}} \rightleftharpoons \underset{\text{conjugate base}}{\mathrm{H_2O}} + \underset{\text{proton}}{\mathrm{H^+}}$$

A base accepts a proton to form its conjugate acid.

$$\text{base} + \text{proton} \rightarrow \text{conjugate acid}$$

4. identify a range of salts which form acidic, basic or neutral solutions and explain their acidic, neutral or basic nature

We know that, $acid + base \rightarrow salt + water$. However the salt formed not always neutral in pH. It is either acidic, basic or neutral. Consider the following cases.

$$\boldsymbol{Strong\ Acid + Strong\ Base \rightarrow Neutral\ Salt}$$

$$\boldsymbol{Strong\ Acid + Weak\ Base \rightarrow Acidic\ Salt}$$

$$\boldsymbol{Weak\ Acid + Strong\ Base \rightarrow Basic\ Salt}$$

Neutral Salt:

$$\begin{gathered}HCl + NaOH \longrightarrow NaCl + H_2O \\ Hydrochloric\ acid\ (strong\ acid) + Sodium\ hydroxide\ (strong\ base) \rightarrow neutral\ salt + water\end{gathered}$$

The $NaCl$ ionises in the water forming Na^+ and Cl^-. As there are no H^+ ions or OH^- ions present, the salt is neutral.

Acidic Salt:

$$\begin{gathered}\mathrm{HCl} + \mathrm{NH_4OH} \longrightarrow \mathrm{NH_4Cl} + \mathrm{H_2O} \\ Hydrochloric\ acid\ (strong\ acid) + Amonium\ hydroxide\ (weak\ base) \rightarrow acidic\ salt + water\end{gathered}$$

The salt NH_4Cl ionises forming NH_4^+ and Cl^-. The NH_4^+ then goes on to react with water,

$$\mathrm{NH_4^+}(aq) + \mathrm{H_2O}(l) \rightarrow \mathrm{NH_3}(aq) + \mathrm{H_3O^+}(aq)$$

The $\mathrm{H_3O^+}$ is acidic.

Basic Salt:

$$\begin{gathered}CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O \\ Acetic\ acid\ (weak\ acid) + Sodium\ hydroxide\ (strong\ base) \rightarrow basic\ salt + water\end{gathered}$$

The basic nature of the salt CH_3COONa can be shown by the hydroxide ions in the equation below.

$$CH_3COONa + H_2O \longrightarrow CH_3COOH + Na^+ + OH^-$$

5. identify conjugate acid/base pairs

An acid and a substance that has one less proton than the acid make a conjugate acid/base pair. Similarly a base which has one more proton than the base make a conjugate acid/base pair.

$$\underset{\text{acid}}{\mathrm{H_3O^+}} \rightleftharpoons \underset{\text{conjugate base}}{\mathrm{H_2O}} + \mathrm{H^+}$$

$HCl \rightleftharpoons Cl^-$
acid conjugate base

$CH_3COOH \rightleftharpoons CH_3COO^-$
acid conjugate base

$$\underset{\text{base}}{NH_3} + H_2O \rightleftharpoons \underset{\text{conjugate acid}}{NH_4^+} + OH^-$$

6. identify amphiprotic substances and construct equations to describe their behaviour in acidic and basic solutions

Amphiprotic substances can act as both acids and bases. They can gain or lose a proton.

To show a substance is amphiprotic construct two equations, with one + H^+ on the RHS to show it gaining a hydrogen ion and the other + H^+ on the LHS to show it losing a hydrogen ion.

$$H_2O + \boldsymbol{H^+} \rightleftharpoons H_3O^+$$
$$H_2O \rightleftharpoons OH^- + \boldsymbol{H^+}$$

7. identify neutralisation as a proton transfer reaction which is exothermic

The basis of all neutralisation reactions is as follows.

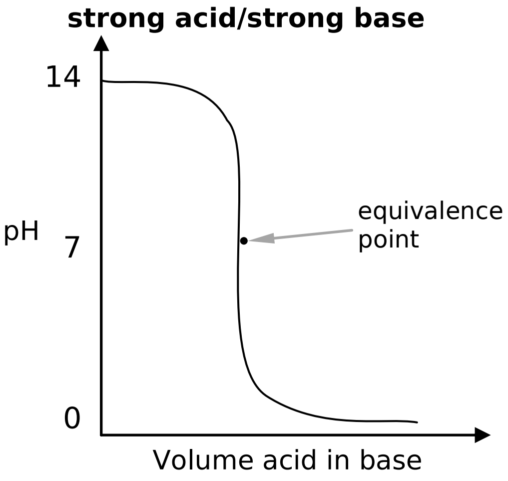
$$H^+_{(aq)} \quad + \quad OH^-_{(aq)} \quad \rightarrow \quad H_2O_{(l)} \quad + \quad \text{heat}$$

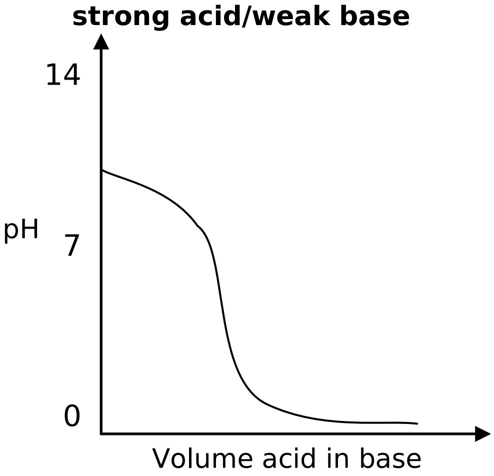
This is a **proton transfer** reaction which is **exothermic**.
Also 1 mole acid + 1 mole base → 1 mole water.

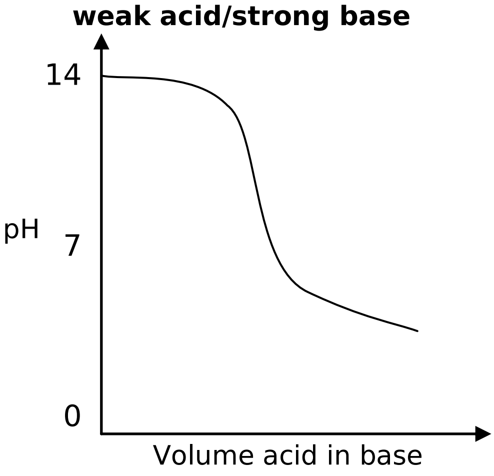
Another useful result is the ionic product of water, $[H^+] \times [OH^-] = 10^{-14}$

8. describe the correct technique for conducting titrations and preparation of standard solutions

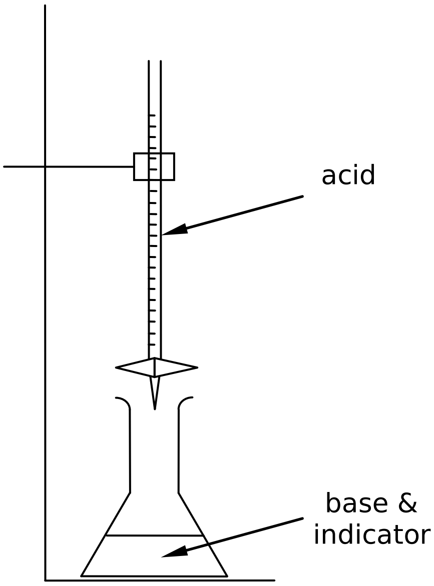
Titrations are used to calculate accurately concentrations of solutions.

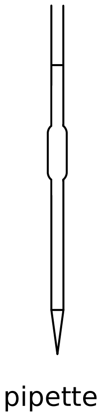


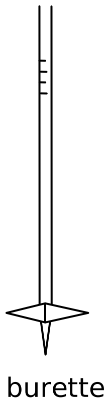




The graphs above is a titration curves. The curves show the process of a titration. In a titration a standard solution of base is placed in a flask. This is done accurately with a pipette. An indicator is added to this solution. Then acid is slowly added, until the indicator shows a change in pH to identify the end point. An indicator is chosen that changes just as the equivalence point is reached. Bromothymol blue is one such indication. In a base it is blue, but the instant the solution becomes neutral or acidic it turns yellow. When the solution in the flask turns yellow, the amount of acid added is measured. This volume is called the titre. The acid is added with a burette, which easily shows the amount of acid added. To ensure the accuracy of the experiment, the flask is washed out with water, the burette is washed out with acid, and the pipette is washed out with base.







A standard solution of base must be present in the flask. A standard solution is one where the concentration is known accurately.

The equiverlance point is when equal moles of H^+ ions and OH^- are present so that (where P and Q are the mole ratios of the acid and base respectively),

$$P \times c_{base} \times v_{base} = Q \times c_{acid} \times v_{acid}$$

As three of the variables are known (both volumes and one of the concentrations) the other concentration can be calculated.

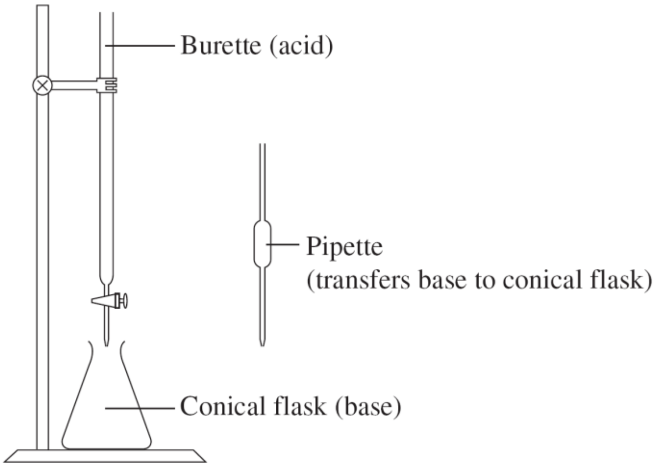


Fig. 48

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See Appendix B for a document which was produced for a practical assessment on this dot point.

9. qualitatively describe the effect of buffers with reference to a specific example in a natural system

A buffer is a solution that resists changes in pH when an acid or a base is added. They are made by mixing together a **weak acid** and the **salt of that weak acid**, or **a weak base** and the **salt of that weak base**.

An example of a buffer in a natural system is blood.

$$CO_{2(aq)} + H_2O \rightleftharpoons H_2CO_{3(aq)}$$

$$H_2CO_{3(aq)} \rightleftharpoons H^+ + HCO_3^-$$

If the pH drops by too much $CO_{2\,(g)}$ dissolving, the equilibrium moves left. If the pH rises then the equilibrium moves right to produce more H^+ ions.

1. gather and process information from secondary sources to trace developments in understanding and describing acid/base reactions

2. choose equipment and perform a first-hand investigation to identify the pH of a range of salt solutions

Neutral Salt: $NaCl$
Acidic Salt: NH_4Cl
Basic Salt: CH_3COONa

3. perform a first-hand investigation and solve problems using titrations and including the preparation of standard solutions, and use available evidence to quantitatively and qualitatively describe the reaction between selected acids and bases

See Appendix B.

4. perform a first-hand investigation to determine the concentration of a domestic acidic substance using computer-based technologies

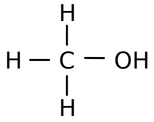
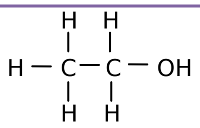
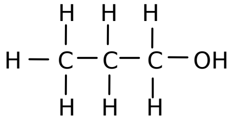
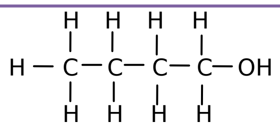
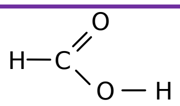
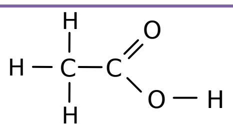
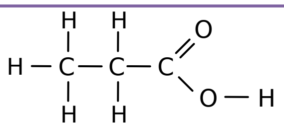
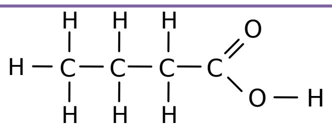
5. analyse information from secondary sources to assess the use of neutralisation reactions as a safety measure or to minimise damage in accidents or chemical spills

Neutralisation reactions can be used to neutralise acid/base chemical spills, however neutralisation reactions are exothermic, which means that this process could be dangerous.

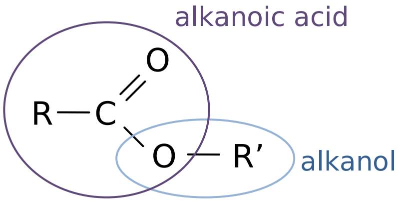
5. Esterification is a naturally occurring process which can be performed in the laboratory

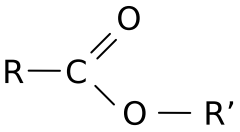
1. describe the differences between the alkanol and alkanoic acid functional groups in carbon compounds

The table below summarises alkanols (remember ethanol from 9.2) and alkanoic acids (remember ethanoic acid from 9.3.2).

	IUPAC Name	Structural Formula	Graphical Structural Formula
Alkanols Functional Group: OH	**Methanol**	CH_3OH	
	Ethanol	C_2H_5OH	
	Propanol	C_3H_7OH	
	Butanol	C_4H_9OH	
Alkanoic Acids Functional Group: COOH	**Methanoic acid**	$HCOOH$	
	Ethanoic acid	CH_3COOH	
	Propanoic Acid	CH_3CH_2COOH	
	Butanoic Acid	$CH_3CH_2CH_2COOH$	

Esters are organic compounds with the general formula R COOR’ where R and R’ are carbon chains. They are formed from alkanols and alkanoic acids. The structural formula of an ester is shown below.





2. identify the IUPAC nomenclature for describing the esters produced by reactions of straight-chained alkanoic acids from C1 to C8 and straight-chained primary alkanols from C1 to C8

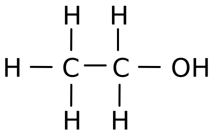
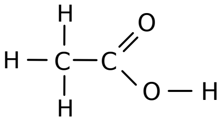
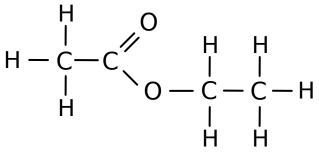
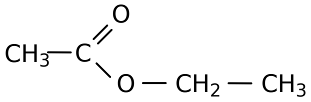
Esters are named as follows: (example followed by general)

ethanoic acid + methanol → methyl ethanoate + H_2O

alkanoic acid + alkanol → alkanol alkanoic acid + H_2O

(ester)

An example of esterification is shown below. I cannot reproduce every ester required by the syllabus as there is 8×8 different esters.

Alkanol	Alkanoic Acid	Ester
Ethanol  CH_3CH_2OH (C_2H_5OH)	**Ethanoic Acid**  CH_3COOH	**Ethyl ethanoate**   $CH_3COOCH_2CH_3 + H_2O$

$$C_2H_5OH(l) + CH_3COOH(l) \xleftrightarrow{H_2SO_4} CH_3COOCH_2CH_3(l) + H_2O(l)$$
$$\textit{ethanol} + \textit{ethanoic acid} \rightleftharpoons \textit{ethyl ethanoate} + \textit{water}$$

3. explain the difference in melting point and boiling point caused by straight-chained alkanoic acid and straight-chained primary alkanol structures

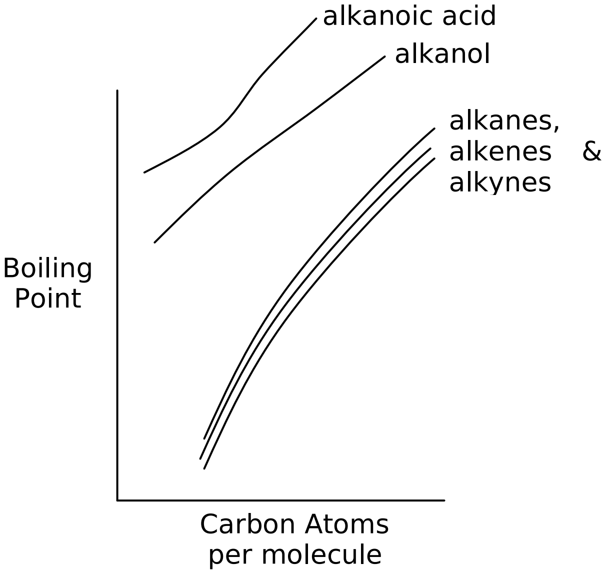


Fig. 49

Alkanes, alkenes and alkynes (**hydrocarbons**) are not polar and do not have hydrogen bonding. They only have **weak dispersion forces**, this gives them low boiling points.

Alkanols have **1 centre of polarity** and form **dipole bonding** and **hydrogen bonding** between molecules and therefore have higher boiling points.

Alkanoic acids have **2 centres of polarity** and **dipole bonding** and **hydrogen bonging** and have even higher boiling points.

4. identify esterification as the reaction between an acid and an alkanol and describe, using equations, examples of esterification

Esterification is the production of an ester from alkanoic acid and an alkanol.

$$RCOOH + R'OH \longrightarrow RCOOR' + H_2O$$

alkanoic acid + alkanol → ester + water

5. describe the purpose of using acid in esterification for catalysis

Heat is used to speed up the reaction and a catalyst of **concentrated sulfuric acid** is used as a **dehydrating agent**.

6. explain the need for refluxing during esterification

Esterification is carried out at high temperatures. Refluxing is used to **prevent volatile substances evaporating**. Refluxing cools the gas that has evaporated back into liquid which returns to the reaction vessel.

7. outline some examples of the occurrence, production and uses of esters

Esters occur naturally in living things. They can be found in **flowers** and **fruits**. They mostly have pleasant smells. They are used in **perfumes** and **fragrances** and to give **flavouring** to **foods**.

1. identify data, plan, select equipment and perform a firsthand investigation to prepare an ester using reflux

The apparatus shown below is used for the preparation of an ester using refluxing. Boiling chips may be used to allow the mixture to boil faster, and the indirect heat source may be provided by a beaker of water that is heated by a bunsen burner.

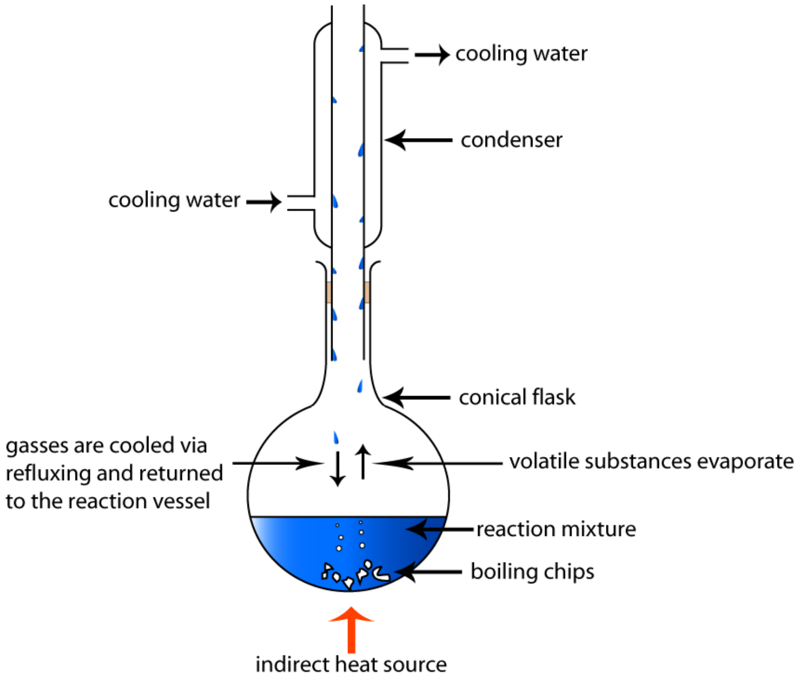


Fig. 50

After several minutes at high temperatures and with a catalyst, we can assume that the reactants in the reaction mixture have reacted and created the ester, the product.

2. process information from secondary sources to identify and describe the uses of esters as flavours and perfumes in processed foods and cosmetics

	Ester	Use
Flavours in processed foods	Octyl ethanoate	Orange flavour
Perfumes in cosmetics	Ethyl ethanoate	Nail polish remover

9.4 CHEMICAL MONITORING AND MANAGEMENT

Contextual Outline:

The state of our environment is an important issue for society. Pollution of air, land and water in urban, rural and wilderness areas is a phenomenon that affects the health and survival of all organisms, including humans. An understanding of the chemical processes involved in interactions in the full range of global environments, including atmosphere and hydrosphere, is indispensable to an understanding of how environments behave and change. It is also vital in understanding how technologies, which in part are the result of chemical research, have affected environments. This module encourages discussion of how chemists can assist in reversing or minimising the environmental problems caused by technology and the human demand for products and services.

Some modern technologies can facilitate the gathering of information about the occurrence of chemicals — both those occurring in natural environments and those that are released as a result of human technological activity. Such technologies include systems that have been developed to quantify and compare amounts of substances.

This module increases students' understanding of the nature, practice, applications and uses of chemistry and the implications of chemistry for society and the environment.

1. Much of the work of chemists involves monitoring the reactants and products of reactions and managing reaction conditions

1. outline the role of a chemist employed in a named industry or enterprise, identifying the branch of chemistry undertaken by the chemist and explaining a chemical principle that the chemist uses

Industry: Pharmaceutical Industry
Role: Ensure products have correct amount of purity (**quality control**)
Branch: Analytical Chemist
Chemical Principal: Using **AAS** for determining amounts of ions present in samples and also performing **titrations** to monitor the concentration of substances in a sample.

2. identify the need for collaboration between chemists as they collect and analyse data

Different specialist chemists specialise in different areas and to work on one specific problem, chemists may be needed from many different branches, thus they need to collaborate to solve the problem.

3. describe an example of a chemical reaction such as combustion, where reactants form different products under different conditions and thus would need monitoring

Combustion of octane (a component of petrol) depending on the amount of oxygen available can produce different products. It can also produce a mixture of the products as shown by the combustion of octane below.

$$octane + oxygen \rightarrow carbon\ dioxide + carbon\ monoxide + carbon + water + hydrocarbon$$
$$C_8H_{18} + 6O_2 \rightarrow CO_2 + CO + 6C + 9H_2O$$

This chemical reaction would need monitoring to ensure the correct amount of oxygen is present to ensure that the products are what are required.

1. gather, process and present information from secondary sources about the work of practising scientists identifying:

- the variety of chemical occupations

Environmental monitoring
Research chemist in **drug development**
Development of **new materials**
Analytical chemist

- a specific chemical occupation for a more detailed study

Research Academic – Researches in areas of chemistry which are still developing.

2. Chemical processes in industry require monitoring and management to maximise production

1. identify and describe the industrial uses of ammonia

- **Fertiliser** (plant nutrient)
- **Explosives** (NH_3 can be used to make nitric acid which is used in some explosives)
- **Manufacture of $NaCO_3$** (sodium carbonate)
- **Cleaning agents**

2. identify that ammonia can be synthesised from its component gases, nitrogen and hydrogen

Ammonia can be synthesised (produced) from its components, nitrogen gas and hydrogen gas. This process is called the Haber process.

3. describe that synthesis of ammonia occurs as a reversible reaction that will reach equilibrium

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

4. identify the reaction of hydrogen with nitrogen as exothermic

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \qquad \Delta H = -92\ kJmol^{-1}$$

The reaction is ΔH negative, i.e. exothermic (the reaction gives off heat).

The reaction profile is given by,

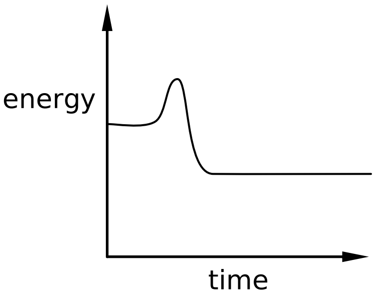


Fig. 51

5. explain why the rate of reaction is increased by higher temperatures

The rate of reaction is increased by higher temperatures. This is because, according to particle theory, the particles are moving and vibrating faster so they collide more frequently. Each time the particles collide they react and form NH_3, thus increasing the rate of reaction. *See dot point 7, last figure.*

6. explain why the yield of product in the Haber process is reduced at higher temperatures using Le Chatelier's principle

As the reaction is ΔH negative, when the reaction goes to the right heat is produced.

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + heat$$

Higher temperatures will result in a shift to the left, due to Le Chatelier's principal to minimise the effect of the change, to decrease the heat produced, and so higher temperatures shift the equilibrium to the left producing less NH_3.

7. explain why the Haber process is based on a delicate balancing act involving reaction energy, reaction rate and equilibrium

The reaction of nitrogen and hydrogen to produce ammonia has a high activation energy, although this can be reduced by using a catalyst. The high activation energy is because N_2 has a very strong triple bond.

The purpose of the Haber process is to produce ammonia. So to get the most ammonia we want the equilibrium to be shifted much to the right to get lots of ammonia. To do this we can do several things, the first is to decrease the temperature of the system. Decreasing the temperature will mean that, due to Le Chatelier's principal, the equilibrium will shift to the right to produce more heat, to minimise the effect of the change, but in the process will produce more yield, more NH_3. However in dot point 5 we saw that the lower the temperature the slower the rate of reaction and so at low temperatures although the ratio of NH_3 produced to N_2 and H_2 produce is quite high, due to the slower reaction rate at these temperatures, the rate that any products are produced is quite low. So in actuality not much NH_3 is produced.

Also the higher the pressure the more yield, but the higher the pressure the slower the reaction rate, because the particles can't move around as much. Also high pressures make it harder to maintain the equipment.

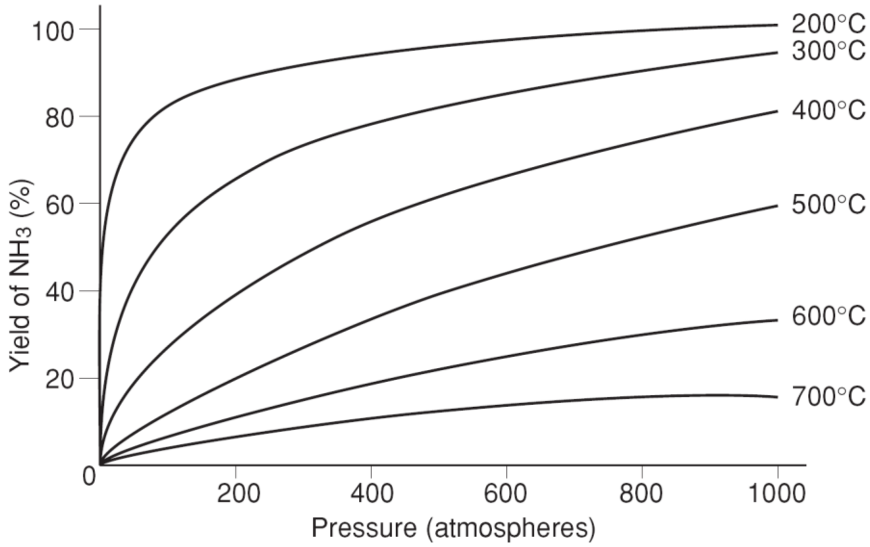
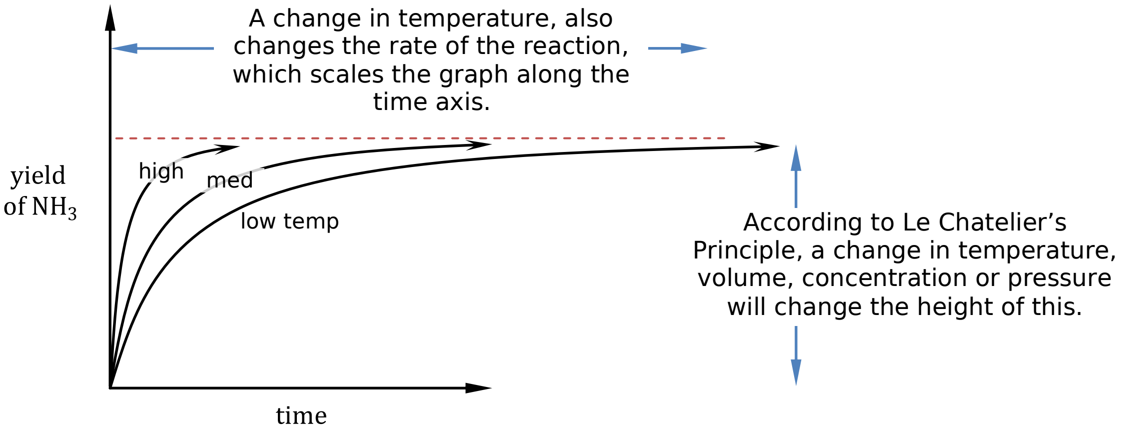


Fig. 52

The diagram below shows the reaction curves for varying factors.



A change in temperature, also changes the rate of the reaction, which scales the graph along the time axis.

According to Le Chatelier's Principle, a change in temperature, volume, concentration or pressure will change the height of this.

Fig. 53

8. explain that the use of a catalyst will lower the reaction temperature required and identify the catalyst(s) used in the Haber process

The **catalyst** used is **iron oxide**. This lowers the **activation temperature** that is needed to start the reaction.

9. analyse the impact of increased pressure on the system involved in the Haber process

Increased pressure on the system involved in the Haber process will put more stress on the pipes. The pipes will need to be thicker to withstand the higher pressures. This makes constructing and maintaining the system more expensive and hazardous.

10. explain why monitoring of the reaction vessel used in the Haber process is crucial and discuss the monitoring required

Monitoring of the reaction vessel is important as it ensures **safety**, and that the process is most **efficient**.

Monitoring Required:

- **Raw materials** going into the reaction vessel (N_2 & H_2 in ratio 1:3)
- **Maintaining temperature** of 400°C - 500°C
- **Maintaining pressure**
- Unused gasses are returned to the reaction vessel
- Ammonia is constantly removed as a liquid

1. gather and process information from secondary sources to describe the conditions under which Haber developed the industrial synthesis of ammonia and evaluate its significance at that time in world history

Haber was in Germany at the time of the war. Germany needed explosives for their war effort. As there supply of ammonia from Chile had been cut off they needed a way to produce ammonia. The synthesis of ammonia allowed for the production of explosives, which prolonged their war effort.

“Early in the 20th century there was need for an industrially synthesized fertilizer to feed the world’s growing population. Also the growing militancy in Germany needed a product for explosives. Haber’s discovery was able to meet these demands. The method also contributed to Germany’s effort in WWI as it insulated Germany from the cutting off of the import saltpeter (the current natural fertiliser) from South America and allowed explosives to be made from nitric acid. Therefore Haber’s discovery had a significant impact on Germany in the early 20th century.”[1]

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[1] *2006 HSC Notes from the Examination Centre – Chemistry*, © 2007 Copyright Board of Studies NSW, ISBN 978 174147 6071, p8.

3. Manufactured products, including food, drugs and household chemicals, are analysed to determine or ensure their chemical composition

1. deduce the ions present in a sample from the results of tests

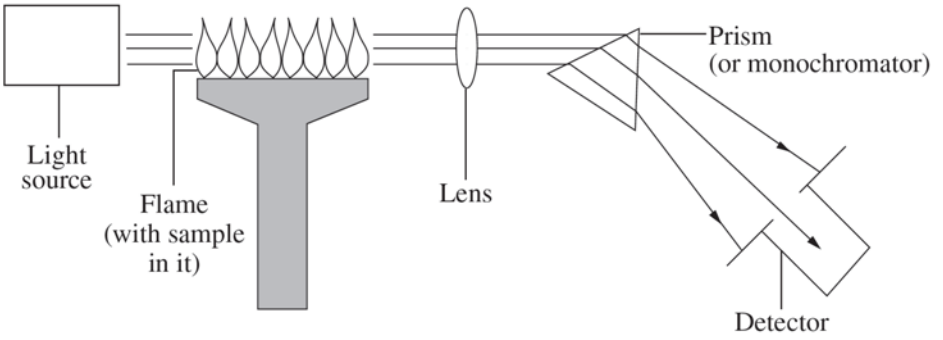
Tests that can be used include **flame tests**, **precipitate tests**, etc.

In a flame test, the ion solution is placed on an uncreative platinum metal. This is held in a flame and the different metal ions will absorb different electromagnetic spectrum which can be seen by the different colours.

In precipitate tests different ions when mixed with certain ions will form certain solids of certain colours.

2. describe the use of atomic absorption spectroscopy (AAS) in detecting concentrations of metal ions in solutions and assess its impact on scientific understanding of the effects of trace elements

When metal ions are placed in a flame, specific electromagnetic radiation wavelengths are absorbed by the metal ion. The wavelengths missing from the light passed though can tell us which element ion the metal is and the strength of the emr can tell us the concentration of the metal ion. The light source is needed to allow the spectra to be absorbed. The flame vaporises the substance which allows the light to pass through to be analysed.



Roland Smith, 2000, Conquering Chemistry, 3rd edition (C) McGraw - Hill Australia Pty Ltd.

Fig. 54

The use of AAS has had a positive impact on scientific understanding of the effects of trace elements. It has allowed for trace elements to be detected that would otherwise go undetected. This has allowed for studies to be conducted that investigate the impact of trace elements.

1. perform first-hand investigations to carry out a range of tests, including flame tests, to identify the following ions:

- phosphate (PO_4^{3-})

Yellow ppt forms when **Ag^+** is added.

$Ag^+ + PO_4^{3-} \rightarrow Ag_3PO_4$

- sulfate (SO_4^{2-})

Add **barium** nitrate solution, and a **white ppt** forms.

$Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

- carbonate (CO_3^{2-})

When HCl is added to the CO_3^{2-} it will **produce gas**, which will turn **limewater** milky.

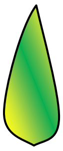
$2H^+ + CO_3^{2-} \rightarrow CO_2 + H_2O$

- chloride (Cl^-)

When **silver** nitrate a **white ppt** is formed which turns purple when exposed to light.

$Ag^+ + Cl^- \rightarrow AgCl$

- barium (Ba^{2+})

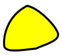


Apple Green Flame

- calcium (Ca^{2+})

Brick Red Flame

- lead (Pb^{2+})



$Pb^{2+} + I^- \rightarrow PbI_2(s)$

When mixed with **I^-** a bright **yellow solid** forms.

- copper (Cu^+)

Green Flame

- iron (Fe^{2+})

Brown ppt forms in **NaOH**.

$Fe^{2+} + 2OH^- \rightarrow Fe(OH)_2$

When placed in a flame, different colours are absorbed by the ion. This can be used to determine which ions are present in a substance. This is the principal used by AAS.

Another way to determine the ion is to place it in substances such as HCl and barium chloride and observe colours of precipitates formed.

2. gather, process and present information to describe and explain evidence for the need to monitor levels of one of the above ions in substances used in society

Lead ions (Pb^{2+}) in the environment must be monitored as it is toxic. Lead is polluted into the environment due to leaded petrol, manufacturing plants, paints, lead fishing sinkers, etc. This lead can get into water ways and be potentially dangerous as it can also kill plant and animal life. Also humans that eat fish which live in polluted water can become ill.

Also, recently in the news, it was found that some children's toys had lead in the paint. This poses a huge potential problem as children put toys in their mouths and lead is toxic.

3. identify data, plan, select equipment and perform firsthand investigations to measure the sulfate content of lawn fertiliser and explain the chemistry involved

Lawn fertiliser contains ammonium sulfate $(\mathrm{NH_4})_2\mathrm{SO_4}$. We can calculate the amount of sulfate in this fertiliser by following some simple steps.

Firstly you need to weigh out a sample of fertiliser and dissolve it in water. Next barium chloride, $\mathrm{BaCl_2}$, is added to precipitate the ammonium chloride.

In principle, this is a simple experiment—weigh out some fertiliser, dissolve it in water, add barium chloride solution to precipitate barium sulfate, then collect, dry and weigh the precipitate.

$$(\mathrm{NH_4})_2\mathrm{SO_4}(aq) + \mathrm{BaCl_2}(aq) \rightarrow 2NH_4Cl(aq) + BaSO_4(s)$$

4. analyse information to evaluate the reliability of the results of the above investigation and to propose solutions to problems encountered in the procedure

5. gather, process and present information to interpret secondary data from AAS measurements and evaluate the effectiveness of this in pollution control

The diagram below shows the atomic absorption spectra of mercury.

Fig. 55

AAS processes have allowed for trace elements to be detected and analysed. This has **helped** pollution control as testing can be done to find these trace elements, which would have otherwise gone unnoticed.

4. Human activity has caused changes in the composition and the structure of the atmosphere. Chemists monitor these changes so that further damage can be limited

1. describe the composition and layered structure of the atmosphere

The atmosphere extends beyond the earth's surface. It consists of gas which is held towards the earth by gravity. The atmosphere is made up of a mixture of gasses, including:

- Nitrogen (~80%)
- Oxygen (~20%)
- Argon (~1%)
- Carbon Dioxide (~0.03%)
- Other gasses (including pollutants)

The different named layers of the atmosphere are related to different altitudes, which correspond to different temperatures.

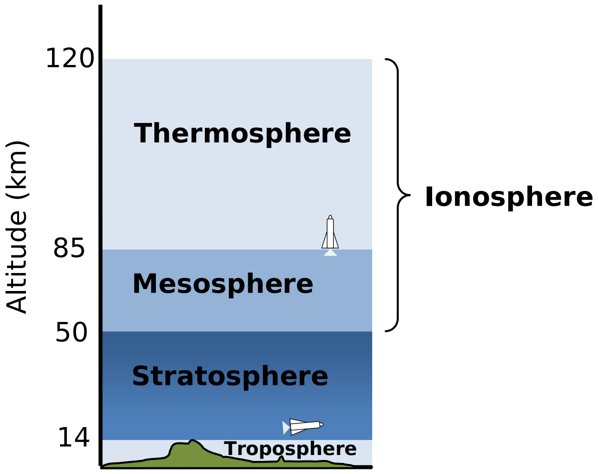


Fig. 56

2. identify the main pollutants found in the lower atmosphere and their sources

The main pollutants found in the troposphere and their source includes:

Pollutant	*Source*	*Effect*
Lead	Cars using leaded fuel	Poisonous
Sulfur Oxides	Burning of fossil fuels. Decomposition of organic matter	Smog, acid rain
Nitrogen Oxides	High temp. combustion, eg. internal combustion engines	Acid rain
Methane	Decomposition of organic matter	Greenhouse effect

3. describe ozone as a molecule able to act both as an upper atmosphere UV radiation shield and a lower atmosphere pollutant

Ozone is O_3. In the **upper atmosphere** it is a **UV radiation shield**.

$$O_3 + UV \rightarrow O_2 + O$$

$$O_2 + O \rightarrow O_3$$

The ozone absorbs UV radiation and decomposes. However the decomposition products then react back to form ozone.

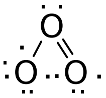
However in the **lower atmosphere** it is considered to be a **pollutant**, as in the lower atmosphere ozone causes,

- Irritation of eyes and airways
- Increase in respiratory conditions such as asthma

4. describe the formation of a coordinate covalent bond

A coordinate covalent bond is a covalent bond in which one atom provides both the shared electrons.

Ozone has a coordinate covalent bond. 3 oxygen atoms are held together with 1 covalent double bond and 1 covalent single bond. The single bond is a coordinate covalent bond.



The Lewis electron dot formula for ozone is,

There is one double bond and one single bond.

5. demonstrate the formation of coordinate covalent bonds using Lewis electron dot structures

An oxygen atom has 6 valance electrons. It has a Lewis electron dot structure of,

Fig. 57

When this bonds to anther oxygen atom to produce O_2, it has a Lewis electron dot structure of,

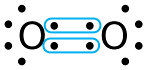


Fig. 58

The two oxygen atoms form a double covalent bond, that is, two of the electrons from each atom are shared between both atoms. When O_2 combines with another oxygen atom to form O_3, two of the free electrons from one of the atoms that is covalently bonded with another oxygen atom shares two more of it electrons to the third oxygen atom to create a single covalent bond. The middle oxygen atom is now sharing electrons and covalently bonded with both the other oxygen atoms.

Fig. 59

Another example of a molecule which has a coordinate covalent bond is NH_4^+,

$$NH_3 + H^+ \rightarrow NH_4^+$$

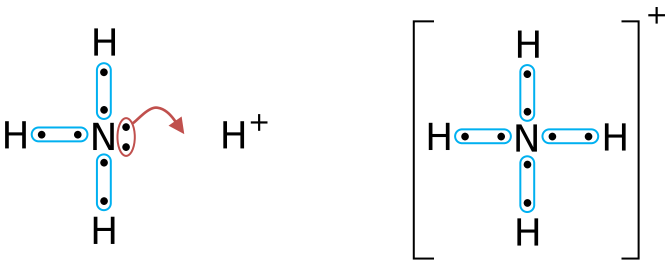
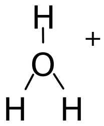
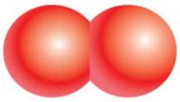
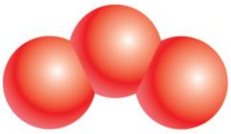


Fig. 60

Another example is, H_3O^+ →



6. compare the properties of the oxygen allotropes O_2 and O_3 and account for them on the basis of molecular structure and bonding

Property	O_2 (Oxygen gas)	O_3 (Ozone)	Reason
Colour	Colourless	Pale Blue	
Odour (smell)	Odourless	Pungent odour	
Effect on human biology	Essential for life	Toxic at same concentration	Ozone is toxic because the coordinate covalent bond is highly reactive
Structure	2 oxygen atoms held together by a covalent double bond. O=O	3 oxygen atoms held together with 1 covalent double bond and 1 coordinate covalent bond. 	
			
Melting Point/Boiling Point (°C)	-219/-183	-193/-111	Ozone has higher melting/boiling points due to stronger intermolecular forces.
Density	About the same as air	About 1.5 times that of air	
Solubility in Water	Sparingly soluble	Considerably more soluble than oxygen gas.	
Stability	Very stable	Unstable. Decomposes into O_2 and O.	
Chemical Reactivity	Highly reactive (oxidising agent)	Very Highly reactive (very strong oxidising agent, much more reactive than O_2)	The single coordinate covalent bond in O_3 requires less energy to break than the double covalent bond in the O_2 molecule.

7. compare the properties of the gaseous forms of oxygen and the oxygen free radical

The oxygen free radical is a single oxygen atom ($O^\cdot$), which is very reactive. Oxygen free radicals are made by the reaction of UV light (upper atmosphere) or lightning (lower atmosphere) on ozone to make oxygen.

$$O_2 \xrightarrow{UV\ light} 2O^\cdot$$

8. identify the origins of chlorofluorocarbons (CFCs) and halons in the atmosphere

CFCs generally come from,

- **refrigerants** in air conditioners or refrigerators
- **aerosol can propellants**.

Halons come from **fire extinguishers** or solvents. However as of the mid 1990's, their use has been banned by international agreement.

9. identify and name examples of isomers (excluding geometrical and optical) of haloalkanes up to eight carbon atoms

Isomers are different structural forms of the same molecular formula. The number of isomers that can exist for a given compound can be determined by drawing the graphical structural formula and looking to see how many different arrangements are possible, remembering that the compound is free to rotate. Haloalkanes are alkanes with at least one halogen atom (group 7) in the alkane. An example of two isomers of a haloalkane is shown below. They both have the same molecular formula of C_4H_8BrCl.

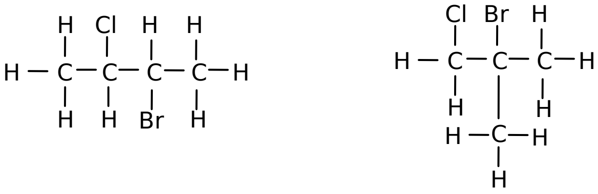
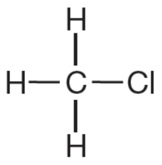
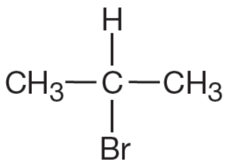


Fig. 61

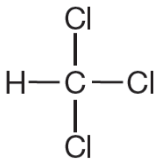
Examples of haloalkanes:



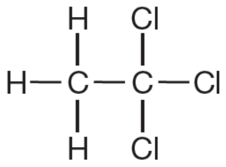
chloromethane



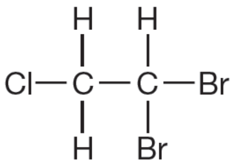
2-bromopropane



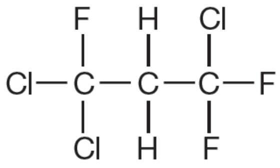
trichloromethane



1,1,1-trichloroethane

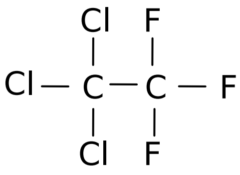


1,1-dibromo-2-chloroethane



1,3,3-trichloro-1,1,3-trifluoropropane

CFCs (chlorofluorocarbons) are a form of haloalkane. CFCs however have a strict condition that they must have no hydrogen present and only the halons chlorine and fluorine. An example is below.



1,1,1-trichloro 2,2,2-trifluroethane

Fig. 62

When naming CFCs, the chlorines are named first, then the fluorine's, then the alkane. The number of isomers of a CFC can be determined as follows. For the structural formula $C_2Cl_3F_3$, first we draw one possibility of the graphical structural formula. Now we see what we can move that is not the same as the first, remembering that you can look at the molecule from whatever direction, so be careful not to count the same thing twice. Below shows the only three isomers of $C_2Cl_3F_3$.

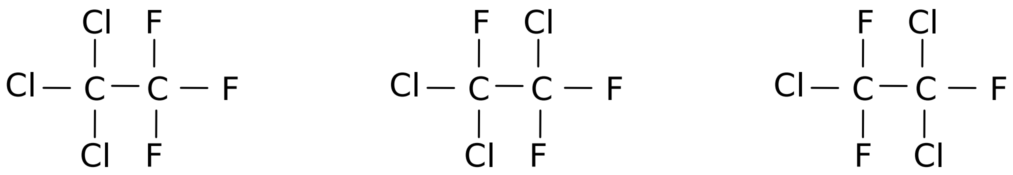


Fig. 63

10. discuss the problems associated with the use of CFCs and assess the effectiveness of steps taken to alleviate these problems

The main problem with CFCs is that they **decompose ozone** in the upper atmosphere and cause a hole in the ozone layer, resulting in **higher UV radiation** levels on earth (because ozone absorbs UV radiation), which can lead to problems such as,

- increased risk of **sunburn** and **skin cancer**
- increased risk of **eye cataracts**

- increased damage to polymers exposed to the sun
- may reduce or hinder plant growth

To alleviate these problems the use of CFCs were banned in the Montreal Protocol. This has proven **effective** as the hole in the ozone has decreased slightly since the Montreal Protocol. However few studies have been done on the long term effects of the alternative chemicals used.

11. analyse the information available that indicates changes in atmospheric ozone concentrations, describe the changes observed and explain how this information was obtained

The concentration of ozone in the upper atmosphere has been **decreasing** since the **industrial revolution**. However in recent times, presumably due to the **banning of CFCs**, the concentration of ozone has **increased**, however the hole still exists and there is a long way to go before it being completely repaired.

Ozone concentration is monitored from **ground based instruments**, instruments in satellites and from instruments in balloons. The ground based instruments **measure the intensity of light received from the sun at a wavelength that ozone absorbs** and then at wavelengths either side of this that ozone does not absorb. A comparison of these intensities gives a measure of the total ozone in the atmosphere per unit area of Earth's surface at that location.

The total ozone mapping spectrophotometers (TOMS) that are on several satellites over the past 20 years work in a similar way to the ground instruments but because the satellites are in orbit they can obtain information about the ozone concentration at various altitudes rather than as an average at a given geographic position.

Huge helium-filled balloons have also been used to carry instruments into the atmosphere to measure concentrations of various substances including ozone as a function of altitude and geographic position.

1. present information from secondary sources to write the equations to show the reactions involving CFCs and ozone to demonstrate the removal of ozone from the atmosphere

Firstly UV light breaks down the CFCs creating a Cl radical, shown as $Cl^{\cdot}$.

$$CCl_2F_2 \xrightarrow{UV\ light} CClF_2^{\cdot} + Cl^{\cdot}$$

This Cl radical decomposes ozone producing ClO and O_2.

$$Cl^{\cdot} + O_3 \rightarrow ClO^{\cdot} + O_2$$

Furthermore the ClO reacts with oxygen radicals (that could be used to create more ozone) producing $Cl^{\cdot}$ and O_2.

$$ClO^{\cdot} + O^{\cdot} \rightarrow Cl^{\cdot} + O_2$$

As you can see, one chlorine radical can decompose huge amounts of ozone, as the chlorine radical is not consumed.

2. gather, process and present information from secondary sources including simulations, molecular model kits or pictorial representations to model isomers of haloalkanes

See orange dot 9.

3. present information from secondary sources to identify alternative chemicals used to replace CFCs and evaluate the effectiveness of their use as a replacement for CFCs

Alternatives include:

- Chlorohydroflurocarbons (eg. $CHClF_2$)
- Hydroflurocarbons (eg. CF_3CH_2F)

They may be effective as they breakdown in the lower atmosphere before they reach the upper atmosphere, however little studies have been done on these alternatives and their breakdown components. It may be some time before we know if they are effective.

5. Human activity also impacts on waterways. Chemical monitoring and management assists in providing safe water for human use and to protect the habitats of other organisms

1. identify that water quality can be determined by considering:

- concentrations of common ions

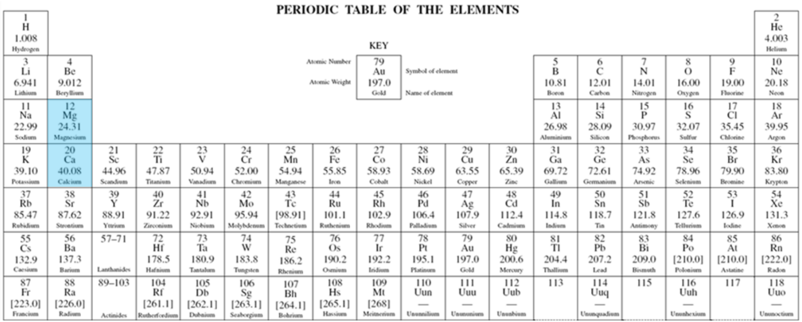
High concentrations of common ions decrease the quality of the water. They may be toxic and damage the living organisms in the water and that consume the water. AAS or testing by conductivity may be used for detection of trace elements.

- total dissolved solids

TDS are measured using gravimetric analysis by evaporation. If the amount of total dissolved solids is too high, it may be harmful to drink.

- hardness

Hardness is due to **calcium** or **magnesium** ions, forming an **insoluble scum**. This reduces the ability of **soap to lather**. To measure hardness, precipitation is used.



PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number 79
Symbol of element Au
Atomic Weight 197.0
Name of element Gold

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.39 Zinc	31 Ga 69.72 Gallium	32 Ge 72.61 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [98.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [210.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [263.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [265.1] Hassium	109 Mt [268] Meitnerium	110 Uun — Ununnilium	111 Uuu — Unununium	112 Uub — Ununbium	113	114 Uuq — Ununquadium	115	116 Uuh — Ununhexium	117	118 Uuo — Ununoctium

Diagram adapted from NSW Board of Studies, Chemistry Periodic Table of Elements

Fig. 64

- turbidity

Turbidity is a measure of **suspended solids** (i.e. not dissolved) in the water. Turbid water appears cloudy or milky, this indicates high turbidity. Water that is very clear has a low turbidity. Turbidity is measured by gravimetric analysis, light meters, or observing the distance you can see through the water.

- acidity

Acidity affects the ability of water to support life, the ability to be drunk and general water quality. It is effected by things such as acid rain, fertilisers, industrial waste. It is measured using indicators or pH meters.

- dissolved oxygen and biochemical oxygen demand

Dissolved oxygen is the amount of oxygen in the water. The more dissolved oxygen the better the water quality. Biochemical oxygen demand is the amount of oxygen that is needed to support the marine life in that area. Things that affect BOD are the amount of fish and plants and also **dead organic matter**. The lower the BOD the better the water quality.

2. identify factors that affect the concentrations of a range of ions in solution in natural bodies of water such as rivers and oceans

- **Rate of river flow**
- **Rock/soil composition of the river bed**
- **Industrial discharge**
- **Irrigation of surrounding areas**
- Solubility of a substance

3. describe and assess the effectiveness of methods used to purify and sanitise mass water supplies

Purifying water involves chemical methods, and sanitising water involves biological methods.

- **Screening** – Screening is a sieve-like device which removes large solid objects, e.g. dead animals, branches, rocks.
- **Sand Filtration** – In sand filtration, water is passed through sand. The sand collects the coagulated solids and the clean water passes straight through.
- **Chemical Treatment** – Chemicals are added which sanitise the water. Such as chlorine which kills bacteria and other living things.

No one method will clean the water for everything. Different methods are better for some things than others. A combination of methods will provide the best results.

4. describe the design and composition of microscopic membrane filters and explain how they purify contaminated water

Different designs of microscopic membrane filters can be used. There are depth filters, surface filters and screen filters. They all have membrane material which when water is passed through, dirt and particles are stoped from also going through. One of the millions of membranes used is shown below (depth filter). Because there are so many of these, the total surface area is large hence the filtration rate is quite high.

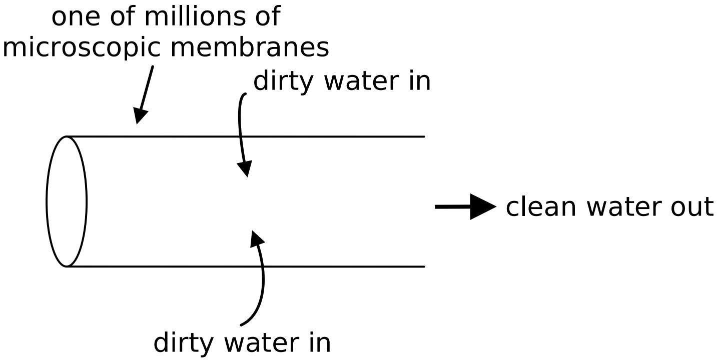


Fig. 65

(Photo by Tim Reid)

1. perform first-hand investigations to use qualitative and quantitative tests to analyse and compare the quality of water samples

Concentrations of common ions tests:
Qualitative test – Flame test
Quantitative test – AAS
For most common ions present in water, the lower the concentration, the better the water quality and vice versa.

Total dissolved solids tests:
Quantitative test – Gravimetric analysis/Evaporation
Quantitative test – Electrical conductivity.

The greater the total dissolved solids, the lower the water quality and vice versa.

Hardness tests:
Qualitative test – Does the water lather easily with soap? If you can then your water quality is good, if not then it is bad.
Quantitative test – Volumetric analysis by titration with EDTA

Turbidity tests:
Qualitative/quantitative test – How far can you see through the sample?

One way to measure turbidity is to use light metres. Another way is to place a cross at the bottom of a measuring cylinder and add water until you can no longer see the cross from the top. A third way is to filter out these suspended solids, with for example microscopic membranes, and calculate the amount of suspended solids.

Another piece of equipment used to measure relative turbidity is a secchi disc. This is a circular disc divided into four quadrants with alternate ones painted black and silver as shown below; a string is attached to the centre. The disc is lowered into the water until the quadrants just become invisible; the length of the string gives a relative measure of the turbidity of the water: the shorter the length of string, the higher is the turbidity. This device is a convenient method of making comparative estimates of turbidity from one location to another or at different times at the same location.[1]

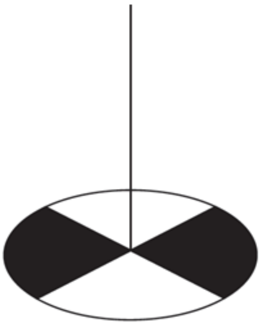


Fig. 66

Acidity tests:
Qualitative test – Litmus indicator
Quantitative test – pH meter/probe
The lower the acidity of the water, the better the water quality and vice versa.

Dissolved oxygen and biochemical oxygen demand tests:
Qualitative tests for biochemical oxygen demand include measuring the amount of organic matter in the water. To test for the amount of dissolved oxygen a visual inspection of the water quality is sufficient.

Quantitative test – Titration or Electrolysis.

The greater the dissolved oxygen, the better the water quality and vice versa. The lower the biochemical oxygen demand, the better the water quality and vice versa.

2. gather, process and present information on the range and chemistry of the tests used to:
- identify heavy metal pollution of water

Heavy metals include mercury and lead. These are toxic. **AAS** may be used to identify heavy metals.

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[1] Smith, R. (2005). *Conquering Chemistry: HSC Course* (4th Edition.). McGraw-Hill Australia Pty Ltd. pg 226.

- monitor possible eutrophication of waterways

Eutrophication involves the decrease in dissolved oxygen in the water. This is caused by the decay of plants in the water as well as phosphates in the water from agriculture and fertilizers. These phosphates promote algal bloom where organic matter grows. There is simply not enough oxygen dissolved in the water to support the plants and the plants decay.

Eutrophication is monitored by performing **dissolved oxygen or BOD tests**. Qualitative tests include **looking at the water**, if it is green and full of algae then eutrophication has occurred. Also if eutrophication has occurred then phosphate ions will most likely be present and so **tests for phosphate ions** can be done.

3. gather, process and present information on the features of the local town water supply in terms of:

- catchment area

The catchment area is the area where rainfall will run into the dam. This area can often be quite extensive as the water will often run into small creeks which runs into other creeks and rivers, which in turn leads to the dam. Also the catchment area can often be quite arbitrary.

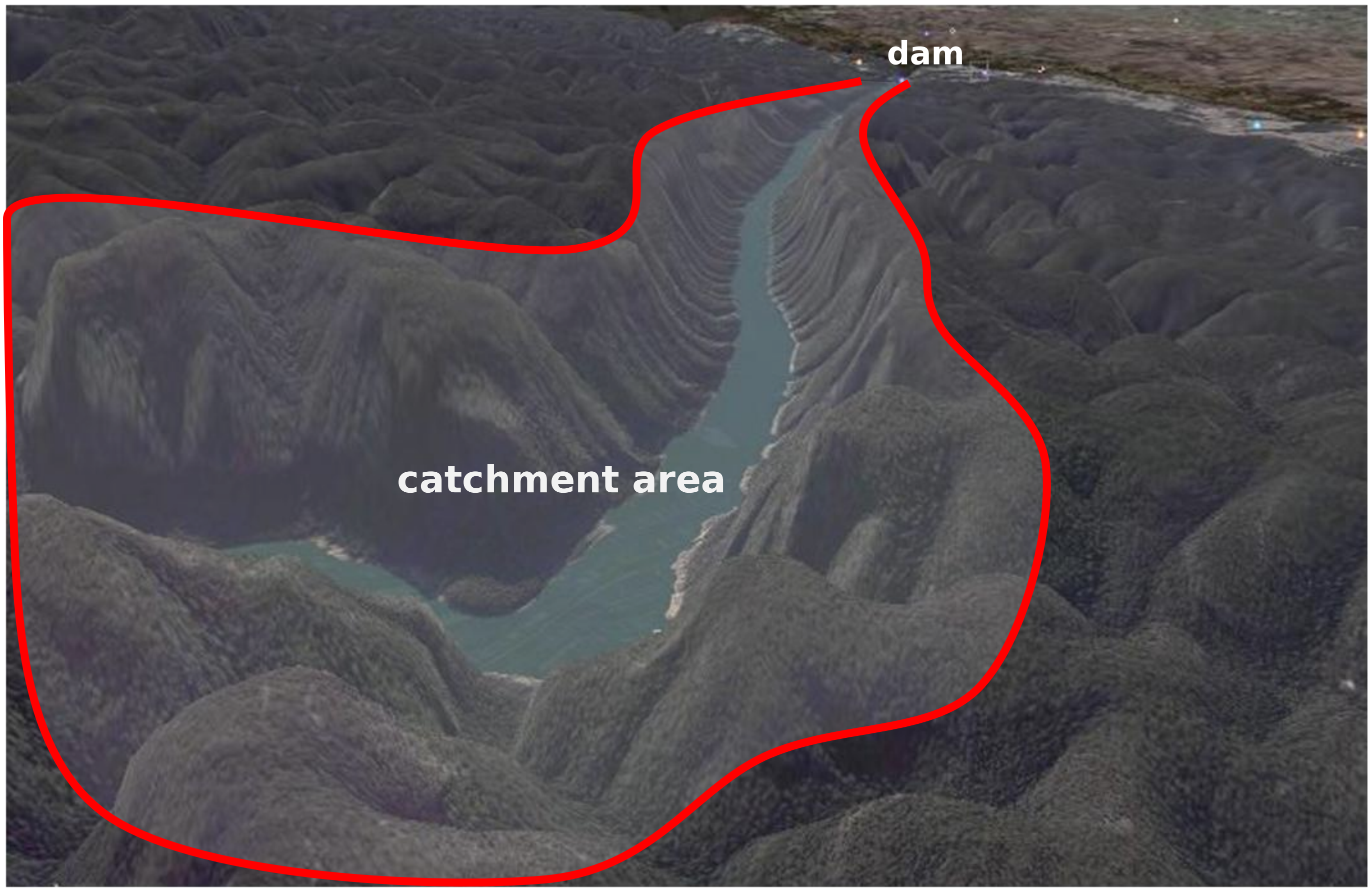


Image © 2007 TerraMetrics, © 2007 Europa Technologies; Image © 2007 DigitalGlobe

Fig. 67

- possible sources of contamination in this catchment

- Ions from minerals
- Pollution from industry
- Acid rain
- Decaying plant and animal matter

- chemical tests available to determine levels and types of contaminants

Chemical Tests	Type of Contaminants
pH test	Acids/Bases

Precipitation	Common ions
AAS	Common ions
Filtration and gravimetric analysis	Total dissolved solids

- physical and chemical processes used to purify water

See orange dot point 3.

- chemical additives in the water and the reasons for the presence of these additives

- **Fluoride** – Added to water to strengthen teeth of humans.
- **Chlorine** – Kills bacteria and viruses. The chlorine sanitises the water.

Contextual Outline:

Industry uses chemical reactions to produce chemicals for use by society. This module develops the ideas that some chemicals have been produced to replace naturally occurring chemicals that are no longer available or are not economically viable. The concepts of qualitative and quantitative equilibrium are further developed.

Industrial chemical processes cover the full range of reactions but concentration on some case studies is sufficient to illustrate the range of reactions and the role of chemists and chemical engineers involved in these processes. This allows some insight into the qualitative and quantitative aspects of the chemical industry and allows a consideration of the analytical processes and monitoring that are necessary for efficient production.

This module increases students’ understanding of the history, applications and uses of chemistry, and current issues, research and developments in chemistry.

9.5 OPTION – INDUSTRIAL CHEMISTRY

X

1. Industrial chemistry processes have enabled scientists to develop replacements for natural products

1. discuss the issues associated with shrinking world resources with regard to one identified natural product that is not a fossil fuel, identifying the replacement materials used and/or current research in place to find a replacement for the named material

Timber is a shrinking resource. The need for timber has lead to the **development of forest plantations** and **artificial timber** materials such as **melamine (chipboard)**.

1. identify data, gather and process information to identify and discuss the issues associated with the increased need for a natural resource that is not a fossil fuel and evaluate the progress currently being made to solve the problems identified

See also above. Artificial materials such as chipboard have proven effective as an alternate material to timber. Also the development of forest plantations has proven effective.

2. Many industrial processes involve manipulation of equilibrium reactions

1. explain the effect of changing the following factors on identified equilibrium reactions

All these factors can be explained by Le Chatelier's principal: If any chemical system in equilibrium is subjected to a change in pressure, volume, concentration or temperature, then the system will react in the direction to **minimise the effect of the change**.

- pressure

Changing the pressure or volume will only affect the equilibrium when there is at least 1 gas present.

If pressure is increased, according to Le Chatelier's principal, the equilibrium will shift in the direction that decreases the pressure again. This is the side with fewer total moles. (Sum the mole ratios on both side of the reaction, and the side with fewer moles is where the equilibrium will shift if pressure decreases.) The opposite happens if pressure increases.

Example: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

As there are 4 moles to 2 moles, if the pressure increased then the equilibrium will shift to the side with less moles to relieve the pressure, which in this case is to the right.

- volume

Changing the pressure or volume will only affect the equilibrium when there is at least 1 gas present.

The effect of changing the volume can be thought of in terms of pressure, as an increase in volume will result in a decrease in pressure, and vice versa.

Example: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

As there are 4 moles to 2 moles, if the volume of the reaction vessel is increased then the pressure will become less and so the equilibrium will shift to the side with more moles to increase the pressure to minimise the effect of the change, which in this case is to the left.

- concentration

If the concentration of a reactant or product is increased then the equilibrium will shift to use up the added chemical. Similarly if the concentration of a reactant or product is decreased then the equilibrium will shift to produce more of that chemical.

Example: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$

Increasing the concentration of N_2 will result in the equilibrium shifting to the right to decrease the amount of N_2.

- temperature

To know the effect of temperature on a reaction we need to know if the reaction is endothermic or exothermic. Exothermic is where the reaction gives off heat ($\Delta H < 0$), and endothermic is where the reaction absorbs heat ($\Delta H > 0$).

With that in mind if the reaction is exothermic we can place $+heat$ on the RHS, and if it is endothermic we can place $+heat$ on the LHS. So according to Le Chatelier's principal, the equilibrium will shift in the direction to minimise the change.

Example: $N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + heat$

So if we decrease the temperature, then the equilibrium will shift to the right to produce more heat to minimise the effect of the change. If we increase the temperature then the equilibrium will shift to the left to absorb some of the heat to minimise the effect of the change.

2. interpret the equilibrium constant expression (no units required) from the chemical equation of equilibrium reactions

For any equilibrium reaction we can calculate a constant, called the equilibrium constant (K).

For the general equilibrium equation:

$$aA + bB \rightleftharpoons cC + dD$$

Where a, b, c, d are the mole ratios and A, B, C, D are the substances. Then:

$$K = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

Where [] is the concentration of the substance at **equilibrium**.

3. identify that temperature is the only factor that changes the value of the equilibrium constant (K) for a given equation

A change in temperature is the only thing that will affect K. The effect of K when a change in temperature is made can be worked out using Le Chatelier's principal.

Example: $$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + heat$$

Adding heat will shift the equilibrium to the left (due to Le Chatelier's Principle). This will create more N_2 and H_2. And as;

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3}$$

, more N_2 and H_2 will result in a larger denominator and hence the value of K will become smaller (decrease).

1. identify data, plan and perform a first-hand investigation to model an equilibrium reaction

See next dot point.

2. choose equipment and perform a first-hand investigation to gather information and qualitatively analyse an equilibrium reaction

$$\underset{\text{brown}}{2NO_2} \rightleftharpoons \underset{\text{colourless}}{N_2O_4} + heat$$

When the reaction was placed in hot water, it turned brown. When it was placed in cold water it turned colourless. This was a qualitative observation and can be used to conclude that the reaction is exothermic. We also noticed that when we placed it in the cold water the pressure decreased, this is because the equilibrium has shifted to the right, and the right has less moles. We also noticed the opposite when we placed it in hot water.

3. process and present information from secondary sources to calculate K from equilibrium conditions

Example Question:

When the Haber process is at equilibrium there are 4 moles of N_2, 8 moles of H_2 and 2 moles of NH_3 in a 5L vessel. Calculate K.

Solution:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

$$K = \frac{[NH_3]^2}{[N_2][H_2]^3} = \frac{\left[\frac{2}{5}\right]^2}{\left[\frac{4}{5}\right]\left[\frac{8}{5}\right]^3} = 0.0488$$

3. Sulfuric acid is one of the most important industrial chemicals

1. outline three uses of sulfuric acid in industry

- **Dehydrating agent** (eg. esterification, dehydration of ethanol)
- **Manufacture of ammonium sulfate fertiliser**
- Used in lead acid batteries, e.g. **car batteries**

2. describe the processes used to extract sulfur from mineral deposits, identifying the properties of sulfur which allow its extraction and analysing potential environmental issues associated with its extraction

To extract sulfur from mineral deposits air and superheated water is pumped into the sulfur deposit. The superheated water melts the sulfur and the air pushes the molten sulfur and steam up out of the ground though the centre pipe. This extraction process is known as the **Frasch Process**.

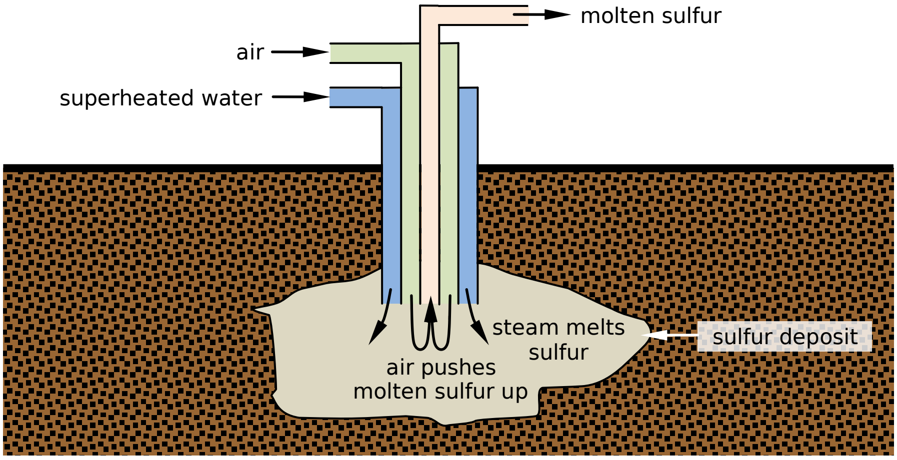


Fig. 68

The main property of sulfur that allows for its extraction is that it has a **low melting point** (less than 120°C). Also sulfur lacks reactivity with water.

Environmental issues associated with its extraction include that **SO_2 gas is released into the atmosphere** which is bad for the environment.

3. outline the steps and conditions necessary for the industrial production of H_2SO_4 from its raw materials

The raw materials are sulfur, oxygen and water. The steps in the production of H_2SO_4 by the contact process are:

- **Sulfur is roasted to produce sulfur dioxide**

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

- **Sulfur dioxide** is oxidised in the presence of a catalyst producing **sulfur trioxide**

$$2SO_{2(g)} + O_{2(g)} \overset{V_2O_5}{\rightleftharpoons} 2SO_{3(g)} + heat$$

- **Sulfur trioxide** is absorbed in water to form **sulfuric acid**

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$$

  However as this reaction is far to exothermic, so instead concentrated sulfuric acid is added to the sulfur trioxide to form oleum ($H_2S_2O_7$), water is then added to this to produce sulfuric acid.

$$SO_3 + H_2SO_4 \rightarrow oleum$$
$$oleum + water \rightarrow H_2SO_4$$

4. describe the reaction conditions for the production of SO_2 and SO_3

For the production of SO_3, $2SO_{2(g)} + O_{2(g)} \overset{V_2O_5}{\rightleftharpoons} 2SO_{3(g)} + heat$, a catalyst of V_2O_5 (vanadium oxide catalyst) is used. Also it is an equilibrium reaction, so pressure, temperature, volume, and concentration affect the yield.

5. apply the relationship between rates of reaction and equilibrium conditions to the production of SO_2 and SO_3

$$S_{(s)} + O_{2(g)} \rightarrow SO_{2(g)}$$

From particle theory we know that if we increase the temperature then the particles are vibrating more and hence collide more, thus the reaction rate is increased. This reaction is not in equilibrium, it goes to completion.

$$2SO_{2(g)} + O_{2(g)} \rightleftharpoons 2SO_{3(g)} + heat$$

This reaction is in equilibrium and so it is affected by a change in temperature, pressure, concentration or volume. Also the temperature affects the rate of reaction due to particle theory, and using a catalyst increases the rate of reaction.

6. describe, using examples, the reactions of sulfuric acid acting as:

- an oxidising agent

$Mg + H_2SO_4 \rightarrow H_2 + MgSO_4$

The Mg is oxidised by the sulfuric acid.

- a dehydrating agent

When ethanol is dehydrated to produce ethylene, a catalyst of sulfuric acid is used.

$$C_2H_5OH \xrightarrow{H_2SO_4} C_2H_4 + H_2O$$

7. describe and explain the exothermic nature of sulfuric acid ionisation

The ionisation of sulfuric acid is a strongly exothermic reaction.

$$H_2SO_4(l) + H_2O(l) \rightarrow H_3O^+(aq) + HSO_4^-(aq)$$

This reaction is exothermic due to the energy released due to the forming of the bond in the H_3O^+.

8. identify and describe safety precautions that must be taken when using and diluting concentrated sulfuric acid

Because the ionisation of sulfuric acid in water has such a large heat production, adding water to (diluting) concentrated sulfuric acid is dangerous. Safety precautions include:

- Wear **protective clothing**
- **ALWAYS ADD ACID TO WATER** (do what you oughter, add the acid to the water) This is because the reaction between acid and water is very exothermic, meaning much heat is produced. And so if you add acid to water then only very dilute acid may boil and spit, rather than having concentrated boiling acid spit. Also when doing this you should be adding the acid **slowly and stir** continually, to prevent the water from boiling.
- **Neutralise** any spills with water.

1. gather, process and present information from secondary sources to describe the steps and chemistry involved in the industrial production of H_2SO_4 and use available evidence to analyse the process to predict ways in which the output of sulfuric acid can be maximised

2. perform first-hand investigations to observe the reactions of sulfuric acid acting as:

- an oxidising agent

Sulfuric acid acts as an oxidising agent when added to zinc metal.

$$H_2SO_4(l) + Mg(s) \rightarrow MgSO_4(aq) + H_2(g)$$

- a dehydrating agent

Sulfuric acid is used as a dehydrating agent in esterification.

Another first hand investigation that can be done to show sulfuric acid acting as a dehydrating agent is by adding sulfuric acid to sucrose to form carbon and water.

$$C_{12}H_{22}O_{11}(s) \xrightarrow{H_2SO_4(l)} 12C(s) + 11H_2O(l)$$

3. use available evidence to relate the properties of sulfuric acid to safety precautions necessary for its transport and storage

It is stored in large reinforced steel tanks because it is very corrosive.

4. The industrial production of sodium hydroxide requires the use of electrolysis

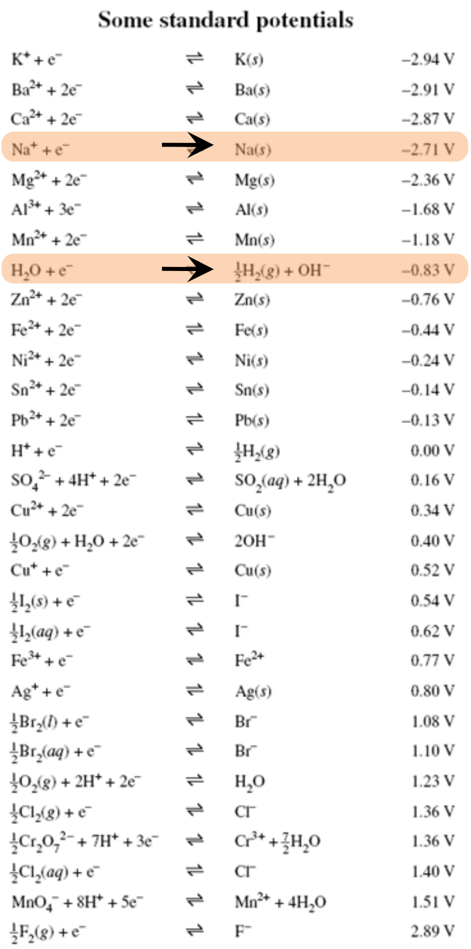
1. explain the difference between galvanic cells and electrolytic cells in terms of energy requirements

In a **galvanic cell** chemical energy is converted into electrical energy. In an **electrolytic cell** electrical energy is applied and a reaction then takes place.

2. outline the steps in industrial production of sodium hydroxide from sodium chloride solution and describe the reaction in terms of net ionic and full formula equations

Sodium hydroxide ($NaOH$) is produced industrially from aqueous sodium chloride ($NaCl\,(aq)$) in solution, however it can also be produced from molten sodium chloride ($NaCl\,(l)$) but this is not the industrially used method.

In sodium chloride solution we have sodium ions, chlorine ions and water. i.e. Na^+, Cl^- and H_2O. These are the species present in the electrolytic cell. We have a cathode and an anode. Firstly let's look at the cathode. We know that reduction occurs at the cathode (Red Cat) and as reduction is loss of electrons the equation must go to the right on the table of standard potentials. From the three species we have only two of them can be possible reactions at the cathode.



Some standard potentials

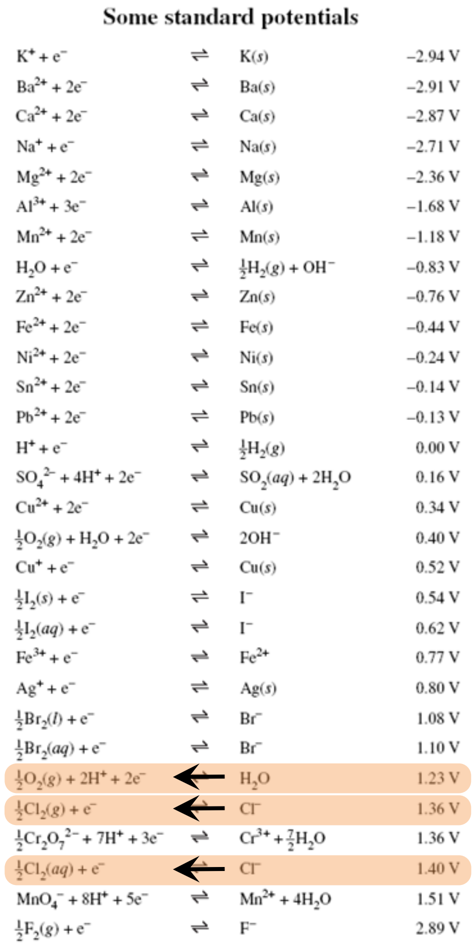
$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightarrow$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightarrow$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Fig. 69

As the reaction of H_2O has a lower voltage, it is more easily reduced and so this is the reaction that occurs at the cathode.

$$H_2O + e^- \rightarrow \frac{1}{2}H_2(g) + OH^-$$

Now let's take a look at the anode reaction. We know that oxidation occurs at the anode and that oxidation is loss of elections and so the reaction must go to the left. The three possible equations are highlighted below.



Some standard potentials

$K^+ + e^-$	⇌	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	⇌	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	⇌	$Ca(s)$	–2.87 V
$Na^+ + e^-$	⇌	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	⇌	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	⇌	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	⇌	$Mn(s)$	–1.18 V
$H_2O + e^-$	⇌	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	⇌	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	⇌	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	⇌	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	⇌	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	⇌	$Pb(s)$	–0.13 V
$H^+ + e^-$	⇌	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	⇌	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	⇌	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	⇌	$2OH^-$	0.40 V
$Cu^+ + e^-$	⇌	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	⇌	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	⇌	I^-	0.62 V
$Fe^{3+} + e^-$	⇌	Fe^{2+}	0.77 V
$Ag^+ + e^-$	⇌	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	⇌	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	⇌	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	←	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	←	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	⇌	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	←	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	⇌	F^-	2.89 V

Fig. 70

We would expect the reaction to be the water reaction, but for unknown reasons it is not. So the next likely equation is the reaction forming the chlorine gas. And so this is the reaction that occurs at the anode.

$$Cl^- \rightarrow \frac{1}{2}Cl_2(g) + e^-$$

These two half equations can be added together to get the full equation.

$$2H_2O(l) + 2Cl^-(aq) \rightarrow H_2(g) + Cl_2(g) + 2OH^-(aq)$$

Now the Na^+ species will react with the OH^- as follows,

$$Na^+ + OH^- \rightleftharpoons NaOH$$

3. distinguish between the three electrolysis methods used to extract sodium hydroxide: by describing each process and analysing the technical and environmental difficulties involved in each process

Process	Technical Difficulties	Environmental Difficulties
Mercury Process	4-5V Required, **Bad**. **High** NaOH Concentration.	**Mercury** is used which is toxic.
Diaphragm Process	4-5V Required, **Bad**. **Low** NaOH Concentration.	**Asbestos** is used which can cause cancer.
Membrane Process	3-4V Required, **Good**. **High** NaOH Concentration (although mercury process is higher).	**None**.

- mercury process

The mercuy process, like the other processes, uses hydrolysis to produce NaOH. The **cathode is mercury** and the **anode is titanium**. The overall reaction is,

$$2\mathrm{Na}^+(\mathrm{aq}) + 2\mathrm{Cl}^-(\mathrm{aq}) \rightarrow \mathrm{Cl}_2(\mathrm{g}) + 2\mathrm{Na}(\mathrm{l})$$

The Na dissolves in the mercury which flows into the decomposer where it is reacted with water.

$$2\mathrm{Na/Hg}(\mathrm{l}) + 2\mathrm{H}_2\mathrm{O}(\mathrm{l}) \rightarrow 2\mathrm{NaOH}(\mathrm{aq}) + \mathrm{H}_2(\mathrm{g}) + 2\mathrm{Hg}(\mathrm{l})$$

Technical Difficulties:
Operational voltage is 4-5V, this is higher than that of the membrane process making it bad. High NaOH concentration is produced, which is good.

Environmental Difficulties:
One environmental difficulty is that **mercury** is used in the process which is a heavy metal. It is toxic and has a range of health problems.

- diaphragm process

In the diaphragm process a **solution of sodium chloride** (NaCl) is **electrolysed** to produce sodium hydroxide (NaOH) with hydrogen (H_2) at the cathode and chlorine (Cl_2) at the anode.

$$2Na^+(aq) + 2Cl^-(aq) + 2H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g) + Cl_2(g)$$

It is named the diaphragm process as the cell has a diaphragm that separates the cathode and anode.

Technical Difficulties:
Operational voltage is 4-5V, this is higher than that of the membrane process making it bad. Low NaOH concentration is produced, which is bad.

Environmental Difficulties:
One environmental difficulty is that **asbestos** is used in the process which causes cancer which can harm animals or living things if it is let out into the environment.

- membrane process

The membrane process is summarised in the diagram below. The cathode and anode compartments are separated by a water-impermeable membrane. This means that ions can pass, but water cannot. Concentrated sodium chloride solution ($\mathrm{NaCl}(aq)$) flows though the anode compartment and water flows though the cathode compartment. The sodium ions and hydroxide ions combine in the cathode compartment to produce sodium hydroxide.

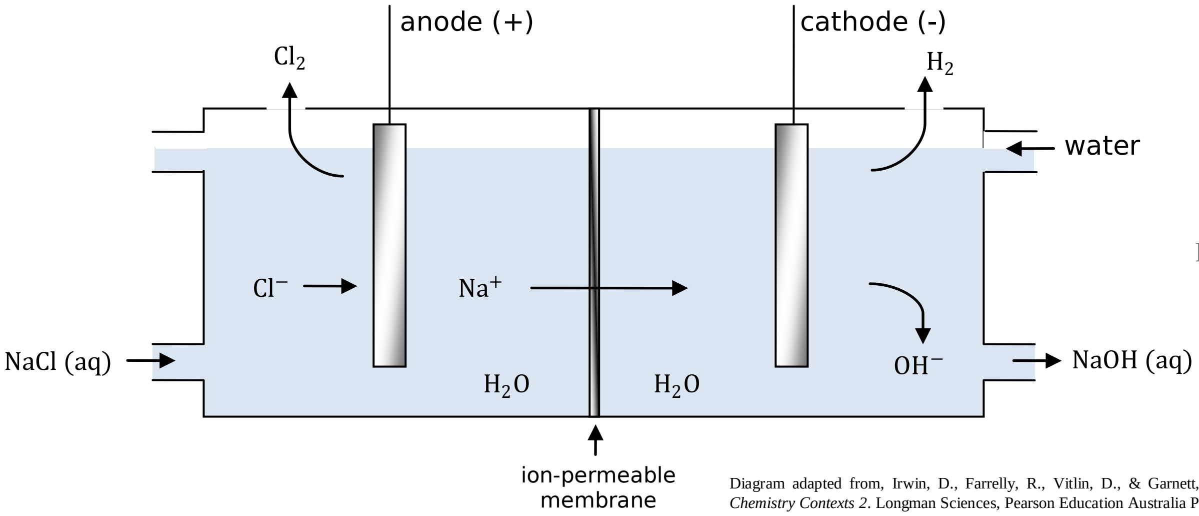


Fig. 71

Diagram adapted from, Irwin, D., Farrelly, R., Vitlin, D., & Garnett, P. (2002). *Chemistry Contexts 2*. Longman Sciences, Pearson Education Australia Pty Limited.

At the anode $Cl^- \rightarrow \frac{1}{2}Cl_2 + e^-$ and at the cathode, $H_2O + e^- \rightarrow OH^- + \frac{1}{2}H_2$. The Na^+ ions move to the cathode compartment and react with the OH^-, $Na^+ + OH^- \rightarrow NaOH$.

Technical Difficulties:
Operational voltage is 3-4V, this is lower than that of the mercury and diaphragm process's making it good. High NaOH concentration is produced, which is good.

Environmental Difficulties:
None, there are no environmental difficulties in the use of the membrane process.

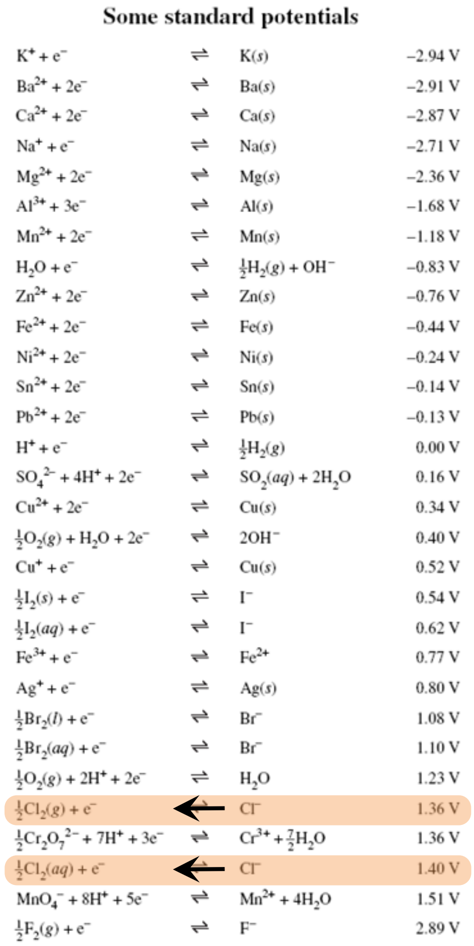
1. identify data, plan and perform a first-hand investigation to identify the products of the electrolysis of sodium chloride

2. analyse information from secondary sources to predict and explain the different products of the electrolysis of aqueous and molten sodium chloride

The electrolysis of aqueous sodium chloride was explained above.

The electrolysis of molten NaCl is slightly different though.

The species present are Na^+ and Cl^-. The possible oxidation reactions at the anode are,



Some standard potentials

$K^+ + e^-$	⇌	$K(s)$	−2.94 V
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$Ca^{2+} + 2e^-$	⇌	$Ca(s)$	−2.87 V
$Na^+ + e^-$	⇌	$Na(s)$	−2.71 V
$Mg^{2+} + 2e^-$	⇌	$Mg(s)$	−2.36 V
$Al^{3+} + 3e^-$	⇌	$Al(s)$	−1.68 V
$Mn^{2+} + 2e^-$	⇌	$Mn(s)$	−1.18 V
$H_2O + e^-$	⇌	$\frac{1}{2}H_2(g) + OH^-$	−0.83 V
$Zn^{2+} + 2e^-$	⇌	$Zn(s)$	−0.76 V
$Fe^{2+} + 2e^-$	⇌	$Fe(s)$	−0.44 V
$Ni^{2+} + 2e^-$	⇌	$Ni(s)$	−0.24 V
$Sn^{2+} + 2e^-$	⇌	$Sn(s)$	−0.14 V
$Pb^{2+} + 2e^-$	⇌	$Pb(s)$	−0.13 V
$H^+ + e^-$	⇌	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	⇌	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	⇌	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	⇌	$2OH^-$	0.40 V
$Cu^+ + e^-$	⇌	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	⇌	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	⇌	I^-	0.62 V
$Fe^{3+} + e^-$	⇌	Fe^{2+}	0.77 V
$Ag^+ + e^-$	⇌	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	⇌	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	⇌	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	⇌	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	←	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	⇌	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	←	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	⇌	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	⇌	F^-	2.89 V

Fig. 72

As the reaction that produced gas Cl has a lower voltage, this is the reaction at the anode,

$$2Cl^-(l) \rightarrow Cl_2(g) + 2e^-$$

The only possible reduction reaction at the cathode is,

$$Na^+(l) + e^- \rightarrow Na(l)$$

And so the overall redox equation is: $2Na^+(l) + 2Cl^-(l) \rightarrow 2Na(l) + Cl_2(g)$

Electrolysis of Molten $NaCl(s)$	Electrolysis of Aqueous $NaCl(aq)$
$\boldsymbol{Na(l)}$ $\boldsymbol{Cl_2(g)}$	$H_2(g)$ $Cl_2(g)$ $NaOH(aq)$

5. Saponification is an important organic industrial process

1. describe saponification as the conversion in basic solution of fats and oils to glycerol and salts of fatty acids

The process of saponification is given below,

$$fat\,/\,oil + base \rightarrow glycerol + salt\ (soap)$$

2. describe the conditions under which saponification can be performed in the school laboratory and compare these with industrial preparation of soap

In the school laboratory soap is produced by heating a mixture of fat/oil and sodium hydroxide (NaOH). The soap produced is precipitated by adding salt and then washed to remove glycerol and NaOH.

In the industrial preparation of soap, the same process is used as for the lab except that the glycerol is fractionally distilled. Also acid is added which separates the fatty acids as an oily layer. They fatty acids are separated and converted to soap.

3. account for the cleaning action of soap by describing its structure

Most dirt is non-polar and so water will not dissolve in it and hence you cannot clean effectively with water. Soaps on the other hand contain a polar and a non-polar end. This means that soaps can dissolve in polar and non-polar substances and hence are good cleaning agents.

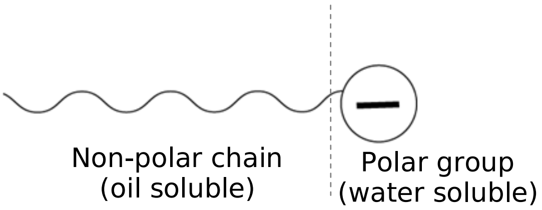
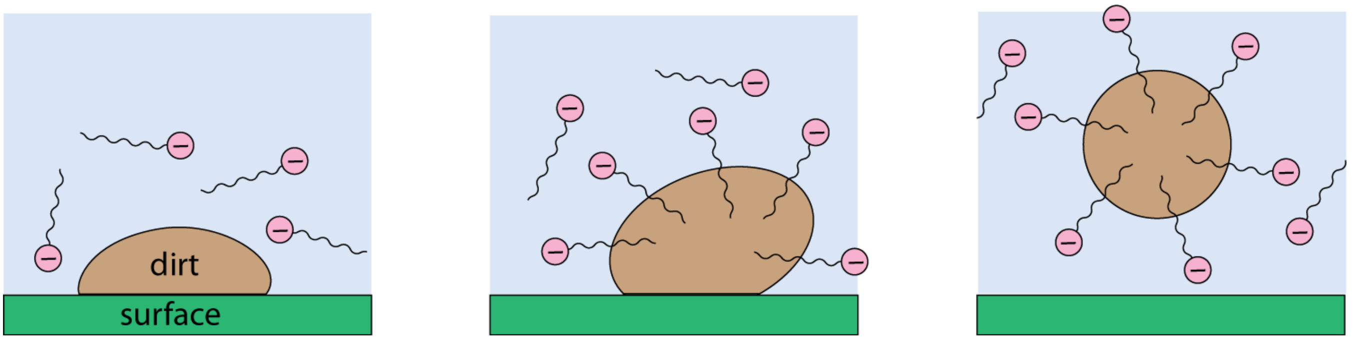


Fig. 73

4. explain that soap, water and oil together form an emulsion with the soap acting as an emulsifier

Diagram adapted from, Smith, R. (2005). *Conquering Chemistry: HSC Course* (4th Edition ed.). McGraw-Hill Australia Pty Ltd. p365.



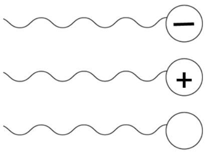
Soap dissolves in water.

Non-polar end of soap attaches to dirt particle.

The dirt, soap and water form an emulsion which acts as an emulsifier, which is suspended in the water.

Fig. 74

5. distinguish between soaps and synthetic detergents in terms of:

	Soaps	**Synthetic Detergents**
Structure of Molecule	 Polar end (negative) and non-polar hydrocarbon chain end.	 Head and non-polar hydrocarbon tail. Head may be +, - or non-ionic.
Chemical Composition	Sodium or potassium salts of long chain fatty acids.	Hydrocarbon with sulfate end.
Effect in hard water	Does NOT lather.	Lathers easily.

- the structure of the molecule

Soaps have a polar end and a non-polar hydrocarbon tail. Detergents have a similar structure, however soaps are anionic (ie. polar end is negative) but detergents may be anionic, cationic or non-ionic.

- chemical composition

Soaps generally contain sodium or potassium salts of long chain fatty acids. Detergents usually contain hydrocarbons with a sulfate end.

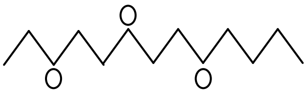
- effect in hard water

Soaps do not lather well in hard water, however detergents do lather in hard water.

6. distinguish between anionic, cationic and non-ionic synthetic detergents in terms of:

- chemical composition

- uses

	Anionic synthetic detergents ⊖	**Cationic synthetic detergents** ⊕	**Non-ionic synthetic detergents** ○
Chemical Composition	 Long hydrocarbon non-polar end (obtained from petroleum). An ionic end that is usually a **sulfate** (SO_4^{2-})	 Long hydrocarbon non-polar end (obtained from petroleum). An ionic end that is usually an **ammonium salt**	 Hydrocarbon chain with uncharged polar groups with the molecule.
Uses	Dishwashing liquids Laundry Detergents	Fabric softeners Mouthwashes Antiseptic soap	Washing cars Automatic dishwashers

1. perform a first-hand investigation to carry out saponification and test the product

In a first-hand investigation to carry out saponification we mixed a fat/oil (see next dot point) with concentrated NaOH in a beaker. This mixture was boiled for about 30mins while stirring constantly and topping it up with water. Once there was only one layer visible, it was cooled and salt was added to produce a white solid soap. Unreacted NaOH, salt and glycerol were washed off leaving soil soap behind.

The product was tested by mixing it with water in a test tube and shaken. If it was soap then a froth formed.

2. gather, process and present information from secondary sources to identify a range of fats and oils used for soap-making

- Coconut oil
- Animal fat
- Vegetable oil
- Olive oil

3. perform a first-hand investigation to gather information and describe the properties of a named emulsion and relate these properties to its uses

Milk is an example of an emulsion. It consists of fat droplets suspended in water. Emulsifying agents are added to the milk to prevent the fat from forming a separate layer.

The properties are that the fat droplets are throughout the milk rather than in a layer at the bottom. This makes it useful as a drink as it looks better and tastes better.

4. perform a first-hand investigation to demonstrate the effect of soap as an emulsifier

Soap was lathered with water in a beaker. Oil was then added. Initially the oil stayed as a layer on the top. But slowly the layer of oil became smaller and the water became darker and dirtier.

5. solve problems and use available evidence to discuss, using examples, the environmental impacts of the use of soaps and detergents

Because soaps are made from natural organic products they are biodegradable. This means that they easily break down by bacteria and do not pose a great danger to the environment.

Phosphates in detergents cause eutrophication of waterways.

6. The Solvay process has been in use since the 1860's

1. identify the raw materials used in the Solvay process and name the products

The Solvay process is a method of making sodium carbonate (Na_2CO_3) from the raw materials:

- **Sodium chloride** (NaCl) – Obtained from brine (salt water)
- **Ammonia** (NH_3) – This is reused during the process so it is not really a raw material.
- **Calcium Carbonate** ($CaCO_3$) – Obtained from limestone in the ground.

The reaction overall reaction is given by,

$$CaCO_3(s) + 2NaCl(aq) \rightarrow Na_2CO_3(aq) + CaCl_2(aq)$$

The products are **sodium carbonate** (Na_2CO_3) and **calcium chloride** ($CaCl_2$). The calcium chloride is considered a waste product.

2. describe the uses of sodium carbonate

The uses of sodium carbonate include:

- **Manufacture of soap**
- **Manufacture of glass**

3. identify, given a flow chart, the sequence of steps used in the Solvay process and describe the chemistry involved in:

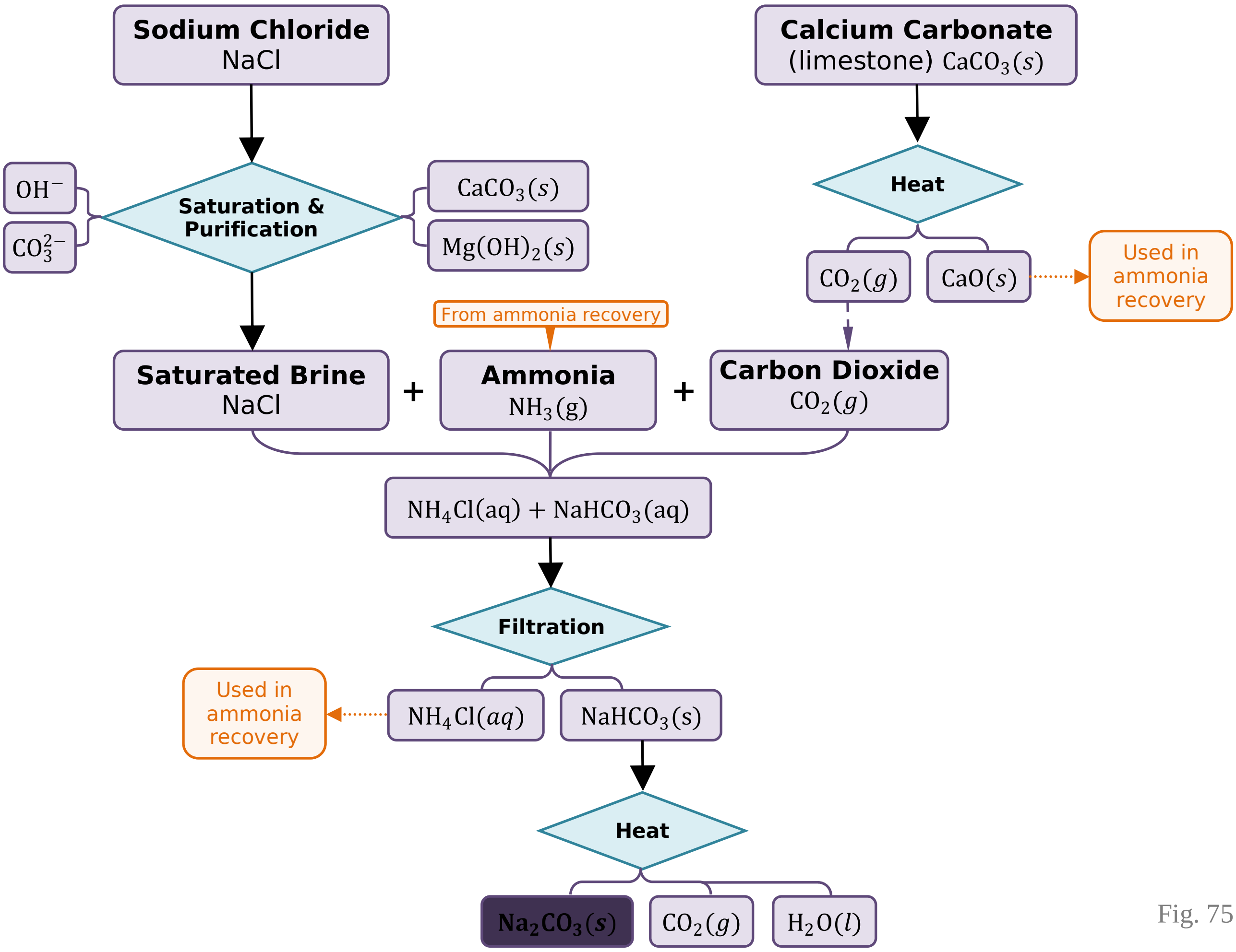


Fig. 75

- brine purification

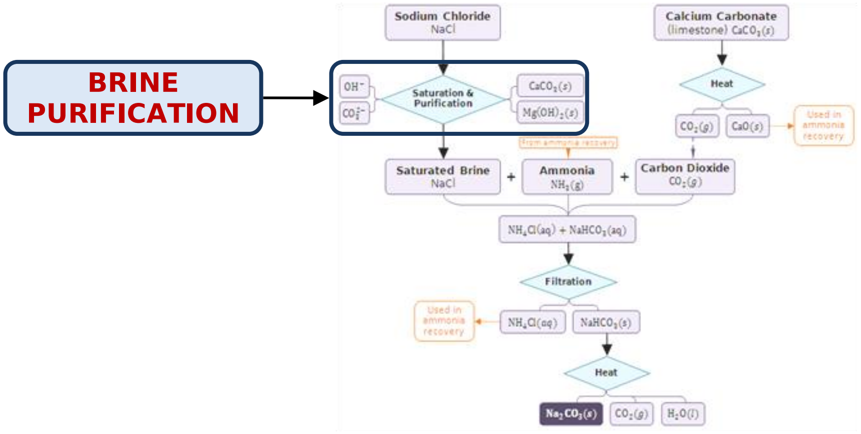


Fig. 76

Brine is salt water. This salt water must be purified to remove calcium and magnesium salts. Calcium salts are precipitated by the addition of sodium carbonate, and magnesium salts are precipitated by the addition of sodium hydroxide.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

$$Mg^{2+}(aq) + 2OH^-(aq) \rightarrow Mg(OH)_2(s)$$

A flocculant (which makes particles stick together) is added so that the precipitates group together and can easily be removed from the brine.

- hydrogen carbonate formation

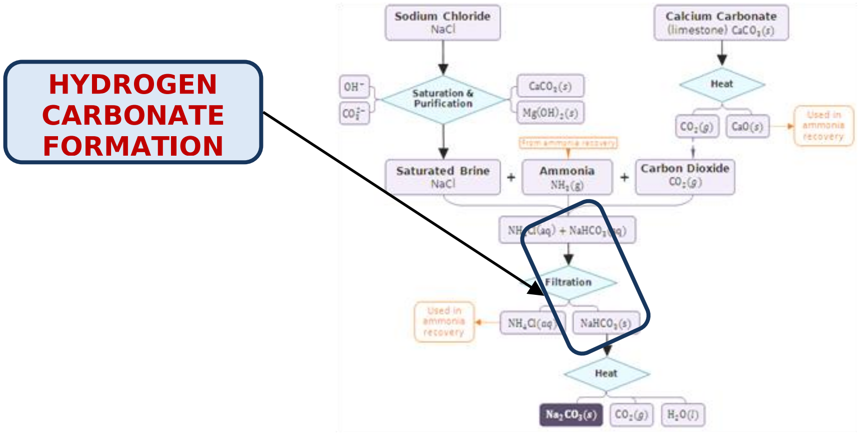


Fig. 77

The purified brine (NaCl), carbon dioxide (CO_2) and ammonia (NH_3) are dissolved in solution forming ammonium chloride (NH_4Cl) and sodium hydrogen carbonate, which ionises in water to form sodium ions and hydrogen carbonate.

$$NaCl(aq) + NH_3(g) + CO_2(g) + H_2O(l) \rightarrow NH_4Cl(aq) + NaHCO_3(aq)$$

- formation of sodium carbonate

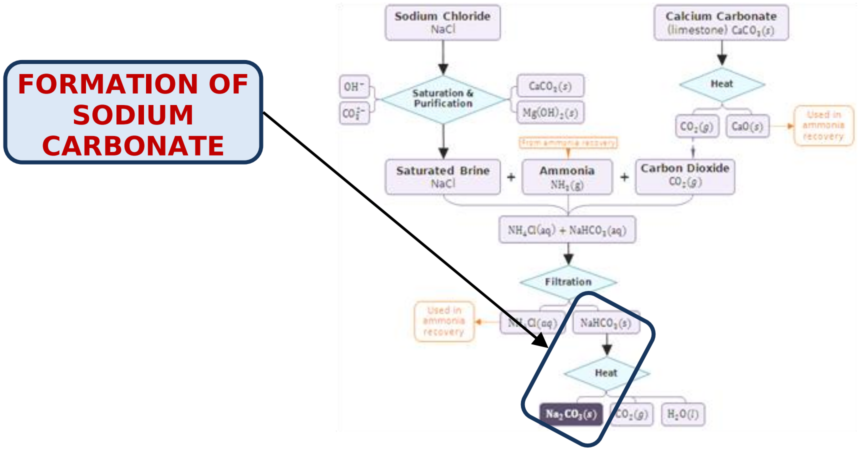


Fig. 78

Sodium carbonate is formed by heating sodium hydrogen carbonate.

$$NaHCO_3(s) \xrightarrow{\text{heat}} Na_2CO_3(s) + CO_2(g) + H_2O(l)$$

- ammonia recovery

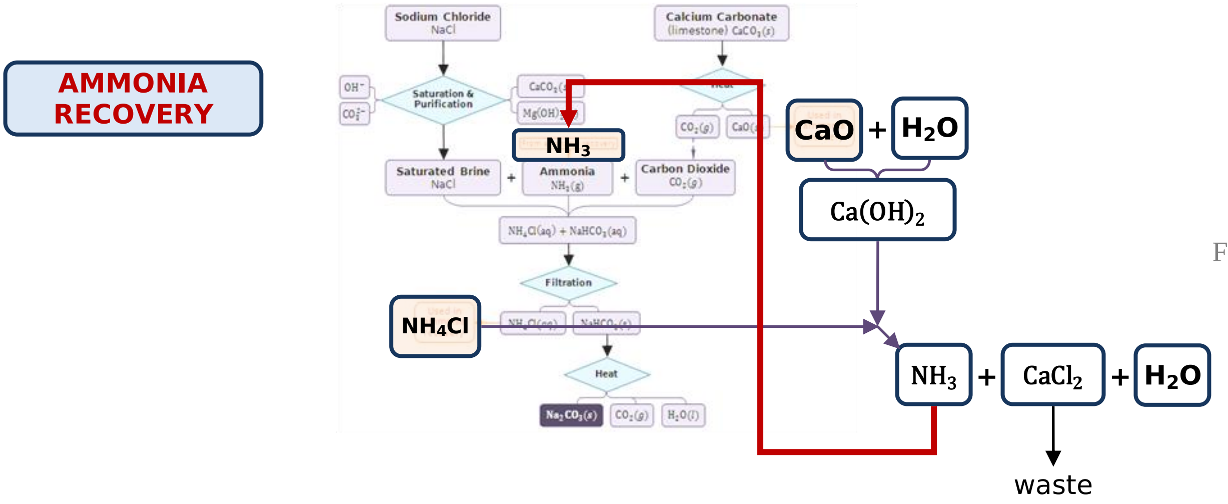


Fig. 79

Firstly calcium oxide, $CaO(s)$, which is produced by the decomposition of $CaCO_3(s)$, is dissolved in water to form calcium hydroxide.

$$CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$$

The ammonium chloride is reacted with this calcium hydroxide to form calcium chloride and ammonia.

$$2NH_4Cl\,(aq) + Ca(OH)_2(s) \rightarrow 2NH_3(g) + CaCl_2(aq) + 2H_2O(l)$$

The ammonia is reused, but the calcium chloride is not, it is waste.

4. discuss environmental issues associated with the Solvay process and explain how these issues are addressed

The main environmental issue associated with the Solvay process is the waste product, **calcium chloride** ($CaCl_2$). Its discharge into rivers causes unacceptable increase in chloride ion concentration which kills organisms and the calcium ions in the water contributes to hardening of the water. Some calcium chloride has been used for de-icing roads, however much more waste calcium chloride is produced than can be used.

Another environmental issue associated with the Solvay process that much heat is produced. Water from rivers is used as a coolant to absorb the waste heat, however this heated water must be cooled before it is returned to waterways. Otherwise it could lower the dissolved oxygen of the lake which could destroy marine life. This form of pollution is known as **thermal pollution**.

Other environmental issues include:

- Mining of limestone

1. perform a first-hand investigation to assess risk factors and then carry out a chemical step involved in the Solvay process identifying any difficulties associated with the laboratory modelling of the step

2. process information to solve problems and quantitatively analyse the relative quantities of reactants and products in each step of the process

3. use available evidence to determine the criteria used to locate a chemical industry using the Solvay process as an example

Criteria used to locate a chemical industry	Solvay process as an example
Close to supply of raw materials	Raw materials include brine (salt water) and calcium carbonate. So the factory is located close to the sea, and near limestone quarry which is sent to factory by train.
Availability of transport of raw materials and final product	
Facilities for waste disposal	Close to river to discharge waste into.

APPENDIX A –

GLOSSARY OF KEY WORDS

Account:	Account for: state reasons for, report on. Give an account of: narrate a series of events or transactions
Analyse:	Identify components and the relationship between them; draw out and relate implications
Apply:	Use, utilise, employ in a particular situation
Appreciate:	Make a judgement about the value of
Assess:	**Make a judgment** of value, quality, outcomes, results or size
Calculate:	Ascertain/determine from given facts, figures or information
Clarify:	Make clear or plain
Classify:	Arrange or include in classes/categories
Compare:	Show how things are **similar or different**
Construct:	Make; build; put together items or arguments
Contrast:	Show how things are different or opposite
Critically (analyse/ evaluate):	Add a degree or level of accuracy depth, knowledge and understanding, logic, questioning, reflection and quality to (analysis/evaluation)
Deduce:	Draw conclusions
Define:	State meaning and identify essential qualities
Demonstrate:	Show by example
Describe:	Provide characteristics and features
Discuss:	Identify issues and provide points **for and/or against**
Distinguish:	Recognise or note/indicate as being distinct or different from; to note differences between
Evaluate:	**Make a judgement** based on criteria; determine the value of
Examine:	Inquire into
Explain:	Relate **cause and effect**; make the relationships between things evident; provide why and/or how
Extract:	Choose relevant and/or appropriate details
Extrapolate:	Infer from what is known
Identify:	Recognise and name

Interpret:	Draw meaning from
Investigate:	Plan, inquire into and draw conclusions about
Justify:	**Support an argument or conclusion**
Outline:	Sketch in general terms; indicate the main features of
Predict:	Suggest what may happen based on available information
Propose:	Put forward (for example a point of view, idea, argument, suggestion) for consideration or action
Recall:	Present remembered ideas, facts or experiences
Recommend:	Provide reasons in favour
Recount:	Retell a series of events
Summarise:	Express, concisely, the relevant details
Synthesise:	Putting together various elements to make a whole

Board of Studies NSW. (2007, July 27). *A Glossary of Key Words (HSC)*. Retrieved from Board of Studies NSW: http://www.boardofstudies.nsw.edu.au/syllabus_hsc/glossary_keywords.html

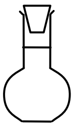
APPENDIX B –

TITRATION PRACTICAL ASSESEMENT

-Acid/Base Titrations can be acid to base or base to acid. The following assumes you add acid to base.-

The question will be along the lines of:
Using sodium hydroxide NaOH provided at 0.100 M, determine the concentration of acetic acid (CH_3COOH) in vinegar. There is approximately 10% w/v acetic acid in vinegar.

Perform appropriate dilutions using correct calculations and equipment



A volumetric flask (above) can be used to measure out a substance to an exact volume.

$$Concentration\ (mol\ L^{-1}) = \frac{number\ of\ moles}{volume\ (L)}$$

In our practical task we will be given a base of known concentration and we will need to find the concentration of an acid in a common household substance. The base (NaOH) is our primary standard, we should use 25mL of it in the flask for each titration. We do not need to dilute the base.

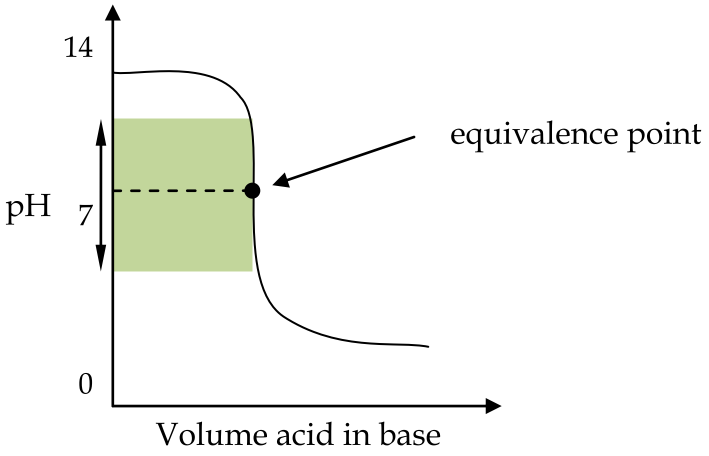
However the acid will need to be diluted, this is because the titration works best and is more accurate when we have equal concentration of the acid and the base. So just say we are given NaOH at 0.100 M, we will need to dilute the acid to make it roughly this concentration.

We are told the approximate amount of acetic acid in vinegar to be 10% w/v. This means that there is 10g of acetic acid per 100 mL of the solution (as 10% = 10/100). However concentration is moles per Litre, so firstly we make it per 1 L, 100g per 1L. Now we need to change the 100g into moles, and as $n = \frac{m}{MM} = \frac{100}{12.01\times2+1.008\times4+16.00\times2} = \frac{100}{60.052} \approx 1.665 mol$. So we have 1.665 mol per 1 L, so concentration is approximately = 1.665 M. This is not close enough to the concentration of the base (0.100 M), so we need to dilute the acid. As the acid is a bit over 16 times more concentrated than the base, we should add 16 times the amount of water than the acid (per volume). So using a 250mL volumetric flask, we would need 15mL of acid and then fill the rest with water, but we can only measure out multiples of 25mL with the pipette, so the closest we can get with a 250mL volumetric flask is $\frac{1.665}{10}$ = 0.1665 M, this is close enough to the concentration of the base (0.100 M), if it was not we could use a 500mL volumetric flask, and/or different multiples of 25mL of the acid.

So as we use 25mL of acid, and then add 225mL of water, the acid has been diluted by a factor of 10 (ie. 10 times). This 10 is accurate, and we will need it later on in the practical task. Remember that the concentration of the acid we used here was approximate; doing the titration will find the exact concentration of the acid.

Justify choice of indicator, with correct chemical equation(s)

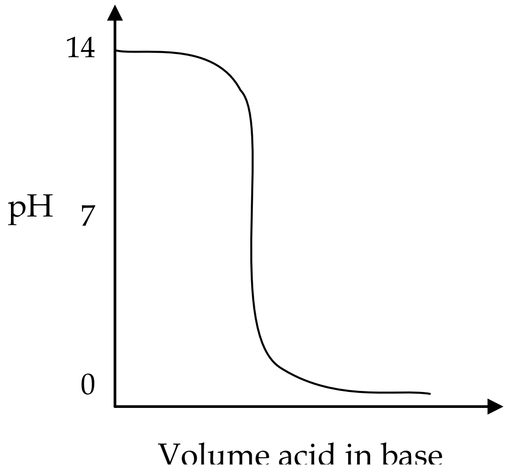
The indicator must be chosen so that a change in colour (end point) will be observed close to the equivalence point.



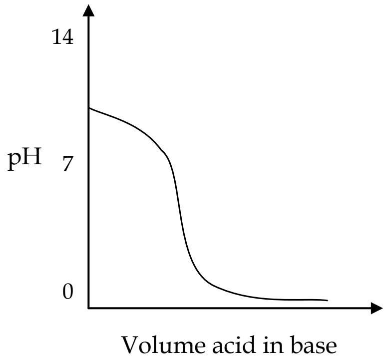
Because of the shape of titration curves indicators can be used. As seen from the graph above there is little change in the volume of the acid when the pH changes from pH 10 to pH 5. Because there is little change an indicator which changes anywhere between pH 10 and 5 is acceptable. If an indicator is chosen that changes colour at for example pH 3, then the volume of acid will be too far away from the correct volume which occurs at the equivalence point.

The equivalence point will move depending upon whether the acid and base are strong or weak, as shown below.

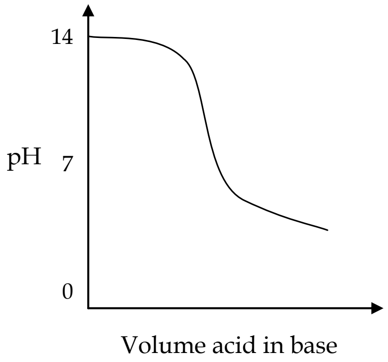
strong acid/strong base



strong acid/weak base



weak acid/strong base



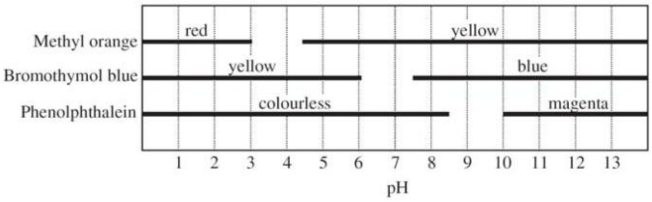
So the equivalence point and from that the indicator can be determine from the strength of the acid and base.

Strong Base (Ionises completely)	**Weak Acid (Ionises partially in H_2O)**
Sodium Hydroxide (NaOH) $NaOH \rightarrow Na^+ + OH^-$	Acetic (ethanoic) acid (CH_3COOH), is a main component of vinegar. $CH_3COOH_{(aq)} \leftrightharpoons CH_3COO^-{}_{(aq)} + H^+{}_{(aq)}$

When the acid and the base react, they form a salt and water, the salt and water form acetic acid, Na^+ and OH^-

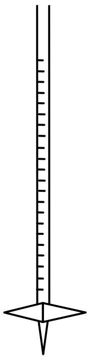
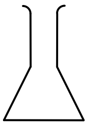
$$CH_3COOH + NaOH \rightarrow CH_3COONa + H_2O \rightarrow Na^+ + OH^- + CH_3COOH$$

Because the OH^- is formed the acid/base solution is basic. Therefore the equivalence point will occur at a pH > 7. So we must use phenolphthalein.

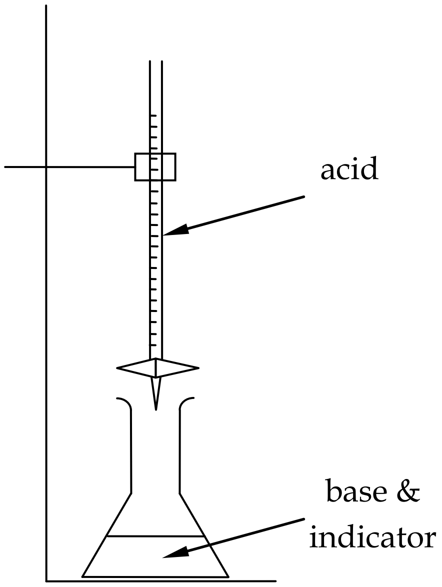


Carry out titration procedure giving suitable results in correct format

Equipment:

 pipette	The pipette is used to accurately measure out 25mL. As it is used to measure out the volume of base into the conical flask, it must be rinsed with base.
 burette	The burette is used to accurately measure out an arbitrary volume. As it will be used to measure the amount of acid added to the conical flask, it should be rinsed out with acid.
 conical flask	This is where the base, acid and indicator are mixed. It should be rinsed with water. Rinsing with base or acid would change the number of moles of base, and therefore is not done.

Apparatus:



Method (This is only a rough method and unadapted to the question. Note: you do not need to write the method out in the practical exam):

1. Obtain a known concentration of base (we are given it), and place it in a beaker.
2. Place an exact amount (usually 25ml or 50mL) into the flask (in apparatus above). Use the pipette to get exact volumes. The flask should be rinsed out with water.
3. Choose an appropriate indicator and place a few drops into the conical flask with the base.
4. Dilute the acid and calculate a dilution factor used (exact).
5. Begin adding the acid using the burette, while stirring constantly.
6. When the indicator changes colour record the amount of acid added.
7. Repeat titration, and record results
8. The concentration of the acid can now be calculated.

Results:

Titration	Initial (mL)	Final (mL)	Titre (mL)
Rough	0.00	23.50	23.50
1	23.50	44.55	21.55
2	0.00	20.25	20.25
3	20.25	41.30	21.05

(Scientifically 1 is not the same as 1.0 The extra zero shows accuracy of measurement. When recording your results don't omit zeros at the end. When measuring the volume from the burette, the measurements should be to two decimal places, with the last decimal place either a 0 or 5. eg. 0.00, 23.00, 23.50, 23.55, 24.95, 21.20, 26.75

Calculate concentration of diluted acid using the titration results

You should know this by now and these are really basic, but essential:
0.1 M is the same as 0.1 mol L^{-1}. They are a measurement for concentration thus, $c = \frac{n}{V}$. [HCl] means the concentration of HCl.

Volume base used = 25.00mL (measured with pipette)
$[base] = 0.100\ M$ (known as base is a standard solution, from the first section) (the 0.100 used here will most likely be different from the one you use in the exam)

Volume acid used = average titre = 20.95mL (You should omit outliers. Almost always omit the rough.)
$[acid] = ???\ M$

$$Xbase + Yacid \rightarrow salt + H_2O$$

(The equation above is the general equation. If the base is NaOH (sodium hydroxide) and the acid CH_3COOH (acetic acid), then the equation is $NaOH + CH_3COOH \rightarrow NaCH_3COO + H_2O$

$$Y \times c_{base} \times v_{base} = X \times c_{acid} \times v_{acid}$$

(as $n = cv$ so you have equal moles of acid and base.)

$$0.100 \times 25 = c_{acid} \times 20.95$$
$$c_{acid} = 0.119\ M$$

Calculate concentration of acid in original substance using the dilution factors

The concentration of the acid, calculated above is based on the diluted solution. We need to apply the dilution factor and calculate the exact concentration of the acetic acid in the vinegar. So, we multiply the above acid concentration by the dilution factor (from first part), $0.119 \times 10 = 1.193\ M$

This gives us the concentration of the original acetic acid in vinegar. You should now take this concentration and calculate the % w/v. So:
1.193 M = 1.404 moles per 1000mL
= 0.140 moles per 100mL
= 8.41 g per 100mL (As $n = \frac{m}{MM}$, $m = n \times MM = 0.140 \times 60.052$)
= 8.41 % w/v

Prepare a risk assessment for this activity, acknowledging at least 2 potential risks

- Acids and bases can be dangerous. Be careful not to spill the acid or base or come in contact with it. This is because it they can eat through clothes, and damage your eyes and skin. Also be carefully not to get any acid or base in your eyes. Ways to minimise the risk include wearing safety glasses, lab coat, closed shoes, gloves, and clearly labelling beakers with acid or base in them. Also correct pouring methods should be employed. If you do get any acid or base on your skin or in your eyes wash thoroughly with water.
- The glassware is a hazard. Be careful not to drop it. If it shatters tiny shards of glass can fly and this is dangerous.

(For this section, for 2 risks, name them, say why it is a hazard and what damage it can do, and also how the risk was avoided or minimised)

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http://www.jaconline.com.au/chemnsw/downloads/chem2/chap-01.pdf.

DATA SHEET

Avogadro constant, N_A .... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and
at 0°C (273.15 K) .... 22.71 L
at 25°C (298.15 K) .... 24.79 L

Ionisation constant for water at 25°C (298.15 K), K_w .... 1.0×10^{-14}

Specific heat capacity of water .... 4.18×10^3 J kg^{-1} K^{-1}

Some useful formulae

$\mathrm{pH} = -\log_{10}[\mathrm{H}^+]$ $\qquad$ $\Delta H = -mC\Delta T$

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

PERIODIC TABLE OF THE ELEMENTS

KEY

Atomic Number	79	Symbol of element
	Au	
Atomic Weight	197.0	
	Gold	Name of element

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.41 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.62 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.94 Molybdenum	43 Tc [97.91] Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanides	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.8 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po [209.0] Polonium	85 At [210.0] Astatine	86 Rn [222.0] Radon
87 Fr [223.0] Francium	88 Ra [226.0] Radium	89–103 Actinides	104 Rf [261.1] Rutherfordium	105 Db [262.1] Dubnium	106 Sg [266.1] Seaborgium	107 Bh [264.1] Bohrium	108 Hs [277] Hassium	109 Mt [268] Meitnerium	110 Ds [271] Darmstadtium	111 Rg [272] Roentgenium							

Lanthanides

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm [144.9] Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.0 Ytterbium	71 Lu 175.0 Lutetium

Actinides

89 Ac [227.0] Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np [237.0] Neptunium	94 Pu [244.1] Plutonium	95 Am [243.1] Americium	96 Cm [247.1] Curium	97 Bk [247.1] Berkelium	98 Cf [251.1] Californium	99 Es [252.1] Einsteinium	100 Fm [257.1] Fermium	101 Md [258.1] Mendelevium	102 No [259.1] Nobelium	103 Lr [262.1] Lawrencium

Where the atomic weight is not known, the relative atomic mass of the most common radioactive isotope is shown in brackets.
The atomic weights of Np and Tc are given for the isotopes ^{237}Np and ^{99}Tc.

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