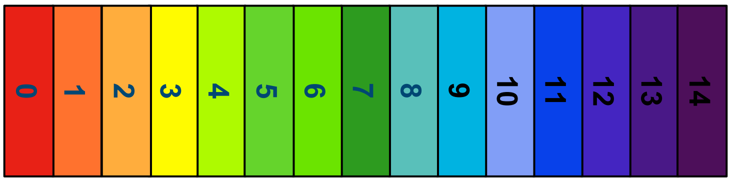
SPECTEMUR AGENDO

Year 10 Science
Water Analysis
-The Universal Solvent

Day after day, day after day,
We stuck, nor breath nor motion;
As idle as a painted ship
Upon a painted ocean.

Water, water, every where,
And all the boards did shrink;
Water, water, every where,
Nor any drop to drink

Samuel Taylor Coleridge, The Rime of the Ancient Mariner



Common Assessment Tasks	**Due date**
Test: Acids and Bases	
Homework Questions	
Practical Reports	
Practical Test: Qualitative Analysis	
Test: Analysis of Water	

Name: ______________________

Form: ______________________

Teacher: ______________________

Table Of Contents

1-1 To The Student

Electronics **Water Analysis** **Traffic**

Minerals to Metals **Genetics/Evolution** **Immunology**

This booklet is one of a series for Year 10 Science. If you miss a class for any reason, you are encouraged to ask a classmate or your teacher of the set homework. Common assessment tasks are the major tasks that all students in Year 9 must conduct to satisfactorily complete the course. The intranet will contain information and diagrams for you to use and can access from home. The intranet will also have PowerPoint and other essential files for you to use to help you prepare for the unit test.

1-2 Science Standards: Water

Chemical reactions involve rearranging atoms to form new substances; during a chemical reaction mass is not created or destroyed (ACSSU178)	• Understand the important role of water in the biosphere • Describe simple tests for cations: - Li^+, Na^+, K^+, Ca^{2+}, Ba^{2+}, Cu^{2+} using flame tests - NH_4^+ using sodium hydroxide solution and identifying the ammonia evolved - Cu^{2+}, Fe^{2+} and Fe^{3+} using sodium hydroxide solution • Describe simple tests for anions: - Cl^-, Br^- and I^-, using dilute nitric acid and silver nitrate solution - SO_4^{2-}, using dilute hydrochloric acid and barium chloride solution - CO_3^{2-}, using dilute hydrochloric acid and identifying the carbon dioxide evolved - PO_4^{3-}, using ammonium molybdate • Perform calculations involving solubility curves • Use the solubilities of ions to predict reactions involving precipitation • Recall the general rules for predicting the solubility of salts in water • Describe how to prepare soluble salts from acids • Describe how to prepare insoluble salts using precipitation reactions • Identify unknown ionic compounds using tests for anions and cations
Chemical reactions, including the reactions of acids, are important in both non-living and living systems and involve energy transfer (ACSSU179)	• Know the difference between base and alkali • Recognise the names and properties of common acids such as sulfuric, nitric, hydrochloric and ethanoic • Recognise the names and properties of common bases such as sodium hydroxide, potassium hydroxide and calcium hydroxide • Describe the properties of and the chemical reactions involving acids and bases - Acid + base - Acid + basic oxide - Acid + carbonate - Acid + hydrogen carbonate - Acid + metal • Describe the use of the indicators litmus, phenolphthalein and methyl orange to distinguish between acidic and alkaline solutions • Understand how the pH scale, from 0–14, can be used to classify solutions as strongly acidic, weakly acidic, neutral, weakly alkaline or strongly alkaline • Describe the use of universal indicator to measure the approximate pH value of a solution • Define acids as sources of hydrogen ions, H+, and alkalis as sources of hydroxide ions, OH^-. Recognise that acids tend to donate protons and bases accept protons • Describe how to carry out simples acid-alkali titrations • Use a spectrophotometer to quantitatively measure the concentration of ions • Recall the parameters measuring the health of a waterway: Temperature, pH, dissolved oxygen, nitrate, phosphate, total solids, BOD, coliform bacteria • Know the role of nutrient ions NH_4^+, NO_3^-, PO_4^{3-} in plant growth, and the effect of excessive nutrients on aquatic systems • Outline the sequence of events leading to eutrophication in a waterway • Describe the processes involved in domestic wastewater sewage treatment

1-3 Chemistry Course Timeline

Week	Concepts and Skills	Class Activities	Homework
1	Water and the Environment Physical properties of water - Polarity, wetting, surface tension Acids and Bases - Strong vs weak acids - Strong vs weak alkalis pH Scale	PowerPoint: *Water Analysis* Teacher Demo: *Properties of water*	Article: *Water – The Essential Material* **Schoology Homework Task 1: Acids and Alkalis** **CHT: Acids and Alkalis**,
2	Acid-base indicators Universal indicator Salts Reactions involving acids and bases - Acid + base - Acid + basic oxide - Acid + carbonate - Acid + hydrogen carbonate - Acid + metal Spectator ions	PowerPoint: *Water Analysis* Practical 1: *Chemistry of Cleaners*	The reactions of Acids pp. 46-47, Q 1-6 Complete reactions involving acids Write formal practical report: C*hemistry of Cleaners*
3	Qualitative Analysis Solubility rules, Solubility curves Predicting precipitation reactions Flame colours to identify metal ions: Li^+, Na^+, K^+, Ca^{2+}, Ba^{2+}, Cu^{2+} Tests to identify cations: NH_4^+, Ag^+, Pb^{2+}, Cu^{2+}, Fe^{2+}, Fe^{3+}, Ba^{2+} Tests to identify anions: - carbonate - nitrate - sulfate - halides - hydroxide - phosphate	PowerPoint: *Water Analysis* Practical 2: *Flame Tests* Practical 3: *Qualitative Analysis of Cations*	**A closer look at neutralisation**, pp. 48-49, Q 1-4 Solubility curves questions **Acids and Alkalis in everyday life,** pp. 50-51, Q 1-5, p. 52, Q 1,2,4, 7-11 **Questions**, pp. 52 -53, Q 1-9
4	Water Treatment of Sewage - stages of treatment - eutrophication of waterways - algal blooms	PowerPoint: *Water Analysis* Practical 4: *Qualitative Analysis of Anions* Practical 5: *Test of unknown ionic solutions*	
5	Instrumental analysis using a Hach spectrophotometer Chemical Tests: Temperature, pH, dissolved oxygen, nitrate, phosphate, total solids, BOD, coliform bacteria	PowerPoint: *Water Analysis* Topic test: Water Analysis	5-2 Chemical Equations Questions

1-4 Task Descriptions

You will work through the activities in this booklet by completing different types of tasks. They are described in the table below and are easily identifiable in the workbook by their symbols. Science uses clear terminology to convey meaning and you are encouraged to become familiar with key definitions. Creating a glossary in your exercise book for these terms and adding new terms as they arise is a recommended method. These, and only these terms will be used in tests and the examination.

📖	Workbook exercises: Exercises to be completed in your exercise books.	🖩	Calculate
		✏	Write the answer in this booklet.
👪	Common Assessment Tasks: These are the major tasks that all students must complete and include unit tests and assignments. Task descriptions and marking schemes can be found on the curriculum portal.	🗣	Explain/Discuss/Debate

1-5 Reference Websites

Schoology: **https://www.schoology.com/login?destination=home**

Ion Analysis **http://www.dartmouth.edu/~chemlab/chem3-5/qual_an/overview/procedure.html**

Periodic Table: **http://www.ptable.com/**

Khan Academy: **http://www.khanacademy.org/video/elements-and-atoms?playlist=Chemistry**

1-6 Setting Out Your Exercise Book

Your workbook is one of the main ways for you to communicate with your teachers. Follow these steps each and every time you use your exercise book.

1. Rule margins in red and ensure they are wide enough for teacher correction
2. Write the date and title of the lesson – this often helps you focus. Use red colour.
3. Diagrams are drawn in pencil, and are large enough to follow easily.
4. Rule a line after each class and homework AND use your workbook sequentially – write on both sides of each page

1-7 The Science Toolbox

A scientist uses a number of tools to answer key scientific questions. Many help organise and illustrate data, including:

Diagrams. Use pencil, simple 2D format, labelled
Experimentation: Fair tests
Flow charts
Graphs
Maps
Photographs
Reports
Surveys
Tables

You should have the correct equipment with you to complete these tasks.

Compass
Protractor
Calculator
Ruler
Pencil and eraser

2-1 Unusual Properties of Water

Activity1: Polarity of Water

Run a thin stream of water from a laboratory tap. Take a piece of perspex or other material rod and charge it by rubbing it vigorously with a piece of sheepskin. Bring the rod close to the stream of water.

Observations:____

____

____

Inference: ____

____

What types of forces are involved with this demonstration? *(Electrostatic, magnetic, gravitational, nuclear)* Bring a magnet near the stream to test for any magnetic forces. ____________________________

Imagine that the rod is positively charged. Predict what will occur if a negative rod is used instead.

Test this with a second rod rubbed with silk, which produces a negative charge.

Explain this observation. ____

____

____

Teacher Activity 2: The Wetting of Surfaces by Various Liquids

1. Gently place a small drop of de-ionised water on one of the surfaces to be tested. Handle the surface using tweezers to prevent oil from the fingers being deposited on it. Observe the extent to which the *deionised water, detergent solution or cooking oil* drops spread out on the surface. Sketch a cross-section of the appearance of the drop.

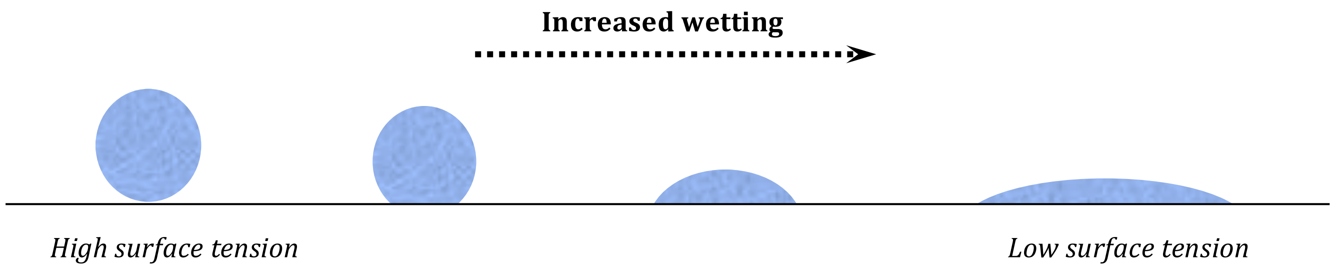
2. Repeat Step 2 for each of the other combinations of liquid and surface. Sketch the cross-section in the table.

	Oil	Water	Detergent Solution
Glass			
Plastic			

Aluminium			
Glad Wrap			
Waxed Paper			
Paper			

Theory

The molecules in a droplet of liquid are attracted to each other by intermolecular bonds. Molecules at the surface experience an overall inward attraction towards the centre of the liquid. Therefore, a drop of liquid tends to form a spherical shape. Imagine the sphere of a water drop floating in a spacecraft travelling to another planet. It may wobble, but maintains its shape.



Back on Earth, in the presence of gravity, when a drop is placed on a solid surface, the molecules in the liquid are also attracted to the atoms or molecules in the solid. If this attraction is much greater than the attraction between the molecules in the liquid, the drop will tend to spread out and *wet* the surface. Surfaces that are wet by water are described as hydrophilic ('water-loving'). If the attraction between the molecules in the liquid is much stronger than the attraction between the particles that make up the solid surface and the molecules in the liquid, the liquid will tend to stay in small drops. Materials that are not wet by water are described as hydrophobic ('water-fearing').

Questions

1. Which surfaces above are hydrophilic? ______________________________

____

Why should clean surfaces be used for this experiment? ______________________________

____

3. What did your observations suggest about the relative strength of the bond between molecules in cooking oil and in water?

____

____

____

4. Does detergent solution wet surfaces to a greater or lesser degree than water? Explain.

____

____

____

Activity 3 (Teacher Demonstration)

Place 9 mL of water overnight in a 10 mL measuring cylinder and let freeze. Let this melt in hot water and measure the final volume.

Why has the water expanded? Have the water molecules themselves changed in size or have the spaces between them changed? Write your prediction here.

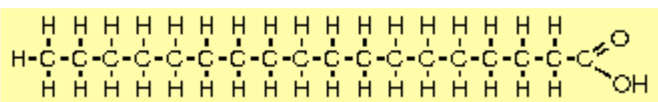
____

____

____

The second idea makes sense, since we don't see evidence of other substances expanding on freezing. This expansion gives us an indication of the spaces between the water particles. As the particles freeze, they arrange themselves into crystal shapes that have small spaces between the molecules. When water exists as a liquid, the molecules are free to move closer, causing the total volume to shrink. *Illustrate molecular model of an ice crystal*.

Activity 4: To Observe the Change in Water Properties with Detergent



Soaps and detergents are commonly used for cleaning and washing in our homes. Their action is chemical in nature and can be observed and explained using chemistry principles. These demonstrations will illustrate some of the properties of these materials. *Note: These demonstrations can be projected using the camera*

1. Fill a beaker with water and float a dry needle or drawing pin on the surface of the water. (This can be done by placing the pin on a tiny piece of tissue and lowering the tissue onto the water. The tissue becomes waterlogged and sinks, leaving the needle floating.) Gently add a drop of detergent to the side of the beaker.

____

2. Fill a water trough with water. Sprinkle lycopodium powder on the surface of the water. Using a dropping pipette, place one drop of detergent in the centre of the beaker.

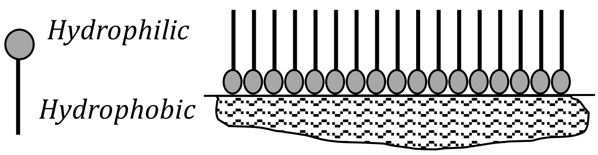
3. Float a plastic clip from a bread wrapper in a beaker of water. Use a dropping pipette to place a drop of detergent in the notch of the clip.

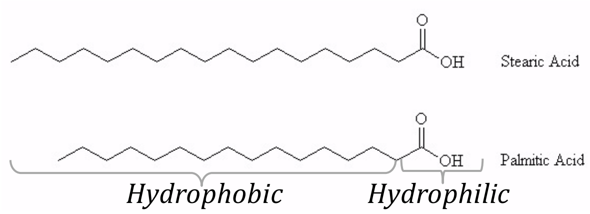
4. Fill a gas jar to overflowing with water. Using a ruler, quickly scrape off the liquid from the top of the container. Count how many metal washers you can add to the beaker using tweezers before the water overflows. Repeat this activity using detergent solution instead of water.

Theory

The cohesive attraction between water molecules causes molecules at the surface of water to experience a pull towards the body of the water. This force (or *surface tension*) makes water behave as if it has a skin. The higher the surface tension, the greater will be its tendency to form droplets.

Detergent molecules have a long hydrocarbon (-CH_2-) 'tail', with a polar 'head' (e.g. –COOH). Oil and petrol are hydrocarbons, do not mix with water and are hydrophobic. However, the head is polar and is attracted to water molecules (hydrophilic). When a surfactant such as detergent is dissolved in water, the hydrocarbon 'tails' are repelled by the water. The detergent particles accumulate at the water surface with their tails pointing out into the air. Since the attraction between these hydrocarbon tails is much weaker than the attraction between water molecules, the surface tension is lowered.





Questions

1. For each activity, explain your observations in terms of surface tension.

2-2 Article: Water - The Essential Material

Below is an article on the importance of water on our planet, where a number of key words and subheadings have been omitted. Read through the article and:

1. Replace the missing words from this list: *acidity, aquifers, biological, climates, dammed, dehydration, dissolving, downstream, ecosystems (2), energy, essential, fertile, gaseous, heat, hydrogen, photosynthesis, respiration, shortage, smallest, soils, solvent, sun, sustainable, transportation, toxic, vaporisation, wastes.*
2. Replace each of the subheadings in the article: *Introduction, Support of Life, Human Uses of Water, Water as a Resource, Chemical and Physical Properties, Aquatic Ecosystems, Abundance / Scarcity, Other Roles of Water, Water Distribution*
3. Complete a table with statements of ten properties and ten uses that illustrate the importance of water on the planet Earth.

Subhead 1

Water is one of the most common substances on our planet. It is transparent, colourless and odourless and is found almost everywhere. Although we drink it, wash in it, clean with it, swim in it and even cook in it, we are probably unaware of its role in our lives unless we are faced with a time when we run out of it. Australia is a dry continent and droughts are a too-common feature of our part of the world.

Water is essential for life. On Earth, life cannot evolve without water. Every living thing has water in its cells. Space probes are scanning the solar system in search of evidence of life, and the first factor being sought is the presence of water. This is why there is so much discussion to find out if there is water on Mars, due to its great importance for life. Because of its significance to life on this planet, water is probably the most studied of all chemicals.

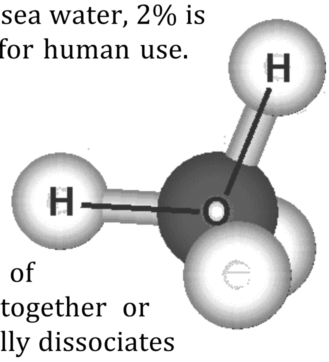
Continent	Average Annual Rainfall
Africa	690
Asia	600
Australia	465
Europe	640
North America	660
South America	1630

Water is a simple molecule, one of the __________ in size. It consists of two _______ atoms attached to an oxygen atom and has a V-shaped molecule.

The planet Earth is unique among the other planets in the Solar System. It has water covering 75% of the surface and constitutes 60-70% of the mass of the living world. It regenerates through the water cycle and mixes easily. If it is so abundant, why do we need concern ourselves with caring for its use?

The problem is, only 1% of the world's water is usable to humans. 97% is salty sea water, 2% is frozen in the polar ice caps and glaciers, leaving a very small proportion available for human use. ________________will bring death much faster than starvation.

Subheading 2



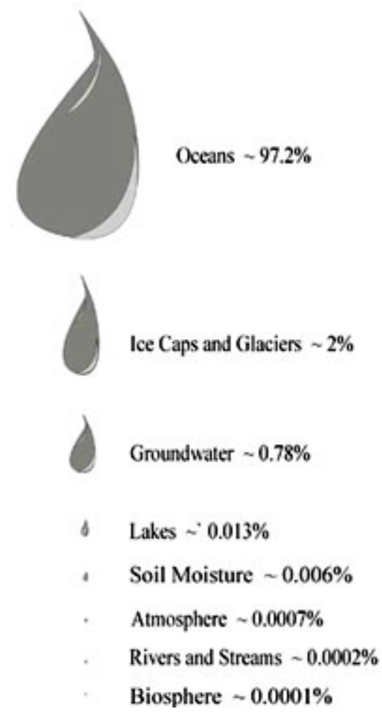
Water is a special chemical substance. In chemical terms, the water molecule is strongly dipolar, with the oxygen end of the molecule containing a slight negative charge (d-), and the hydrogen end slightly positive (d+). This property makes water an effective ___________, particularly for ionic substances such as salt. The small size of hydrogen atoms makes it possible for molecules of water to effectively bond together or chemically associate, particularly at lower temperatures. However, water also partially dissociates into very minute concentrations of acid (H_3O^+)and base (OH^-) ions; a characteristic which leads to the use of the pH scale to measure relative __________ or alkalinity.

The chemistry of water leads to some very interesting, and important, physical properties. At the temperatures and pressures found on the surface of this planet, water can be found in all three physical states: solid, liquid and ___________. It is the *only* natural substance to exist in all three states. While pure water freezes at 0^oC, its maximum density is reached at 4^oC. This permits the unusual property of solid water (ice) floating on liquid water. This inter-molecular attraction between the slightly positive and negative ends also accounts for the strong surface tension exhibited by liquid water. Small animals are able move about on its surface and this surface tension aids water to penetrate tiny spaces in the soil and elsewhere. In its liquid form, water has a relatively high viscosity, thereby slowing its rate of runoff from the land and keeping it more available for terrestrial life.

Water has a much higher boiling point than its nearest chemical relatives, making it relatively efficient in the high temperature conversion of heat into work. Greater heat is required to vaporise water (latent heat of vaporisation) than that needed to vaporise an equal weight of any other liquid. This makes water vapour a good carrier of energy and is responsible for its dominant effects in stabilising the ___________ of the earth. Indeed, more heat is required to raise the temperature (heat capacity) of water than is required to raise the temperature of an equivalent weight of any other liquid. This means that water, even in its liquid state, can transport great quantities of heat and have major effects on climate.

Pure water is transparent to the visible wavelengths of light, with maximum transmission of light in the blue portion of the visible spectrum. It is also reasonably transparent over many of the wavelengths used by plants for ___________, thereby supporting plants growing in oceans and other water bodies. Water vapour in the atmosphere, unlike liquid water, absorbs the sun's ultraviolet radiation which otherwise would be extremely harmful to life on earth. Both liquid water and water vapour are non transparent to the infrared radiation which is given off by the earth, thereby preventing much of this heat from being lost to space and keeping Earth's temperatures at levels that support life.

Relative Distribution of the World's Water Supply



While oxygen atoms comprise almost 80% of water by weight, this oxygen is chemically bound and not available to plants and animals. However, some molecules of oxygen do dissolve in water, particularly at lower temperatures. This dissolved oxygen is available for ___________ and permits animals to inhabit lakes, streams and oceans.

Subheading 3

These special properties of water would be interesting, but not nearly as important, were not water so abundant here on earth. With an estimated 1.4 billion cubic kilometres of water on this planet, its special properties become extremely important. Not all water, however, is readily available. The oceans, which cover well over two-thirds of the earth's surface, also contain about 97% of the planet's water. However, there are also substantial quantities of fresh water in various forms and locations. Almost 90% of this fresh water is locked up in polar ice-caps and glaciers. Only about 0.3% of all water on earth is currently available as fresh water, and almost all of this is located in natural underground reservoirs or ___________. Less than 1 of every 5,000 litres of water on earth can be found as either surface or atmospheric fresh water. However, this tiny fraction still represents an estimated total volume of more than 200,000 cubic kilometres, enough to cover all of Australia to a depth of 17 metres.

How, then, is all this water so essential? Why, with so much water around, do we have so many problems finding it and using it?

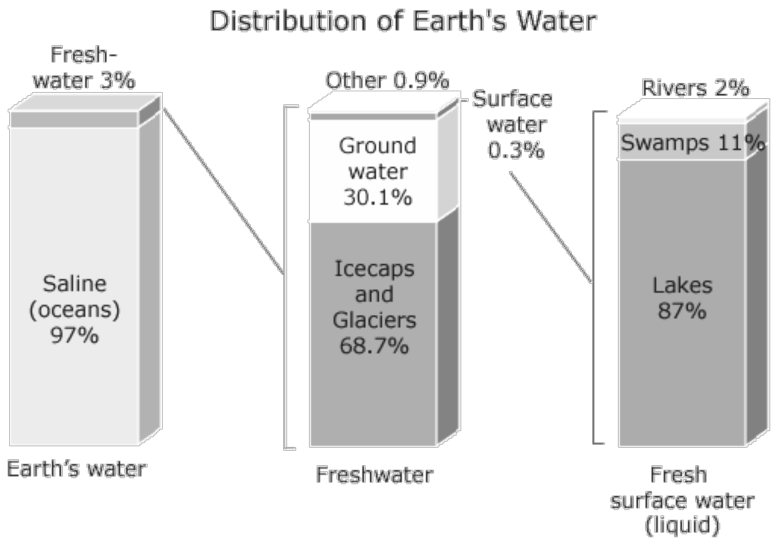
Subheading 4

As we noted earlier, water readily dissolves most salts. However, water is a poor solvent for proteins and other large organic molecules in living cells. This means that liquid water can transport nutrient elements to and within living cells without dissolving and destroying the organic molecules of which cells are made. Water also transports waste elements away from cells. Thus, all living cells contain water, with the proportion ranging from 3-5% in seeds to perhaps 95% in very young plant tissues and jellyfish. This water penetrates the cell protoplasm, but does not dissolve it. Increased water content leads to increased chemical or ___________ activity within the cell. Without water, there would be no life.

This means that the distribution of life on earth is highly dependent on the distribution of water. Our needs, both metabolically and otherwise, are often affected by the distribution of water and by competition for available water.

Subheading 5

Of course, water is not evenly distributed, and this has a major impact on us, both as living organisms and as a complex social species. Most water is concentrated in the oceans. Even on land, the distribution of water varies greatly because of weather patterns, evaporation rates, and other factors.



Humans often choose to live in areas with dry, sunny climates. At the same time, we require large quantities of water for domestic, recreational, agricultural, and industrial uses. This inevitably leads to water ___________ problems and water redistribution schemes are undertaken. In other situations, human populations settle on fertile coastal plains or in river valleys. These areas are susceptible to flooding during storms and spring run-off. Again, issues of water management become important.

In either case, engineering solutions are usually available to alter water distribution, although often at high cost. Governments are faced with demands to construct larger capacity dams to divert water hundreds of kilometres to thirsty cities. We must attempt to weigh fairly the costs and benefits, both short- and long-term, before undertaking such engineering projects.

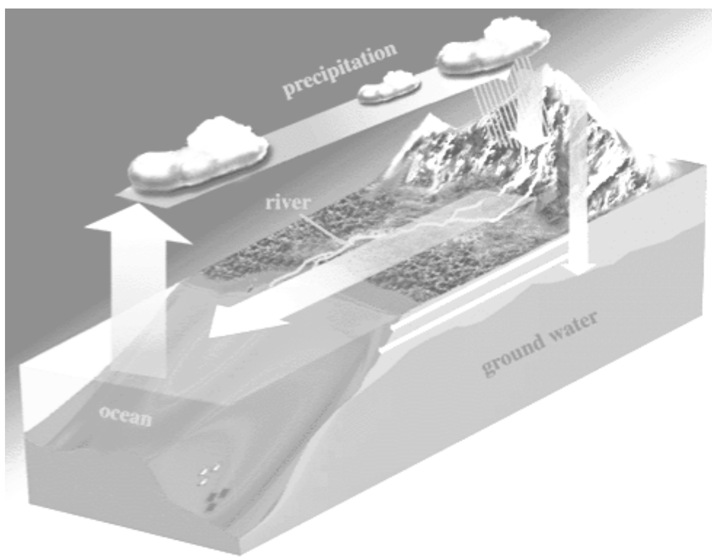
Subheading 6

Direct support of life, while most important, is only one of a multitude of roles played by water on our planet.

As noted earlier, water is extremely important as a modifier of climate. It stores heat in great quantities, transports it around the globe, both in ocean currents and in atmospheric vapour, and helps to retain stored ____________ at the earth's surface by reducing its radiative loss to space.

As an effective solvent, and as a physical mass releasing energy as it moves downhill, water is a major modifier of the earth's surface. It erodes and breaks down rock, carries materials downstream, and deposits these eroded mineral particles in depressions where they can combine with organic materials to form ___________. It can also erode these soils, leaving a greatly altered landscape. The very shape of our planet's surface is a product of water and its distribution.

Of course, the ability of water to run downhill and shape the earth's surface is dependent on a process known as the water cycle or hydrologic cycle. In this cycle, heat energy from the sun causes liquid water and ice to evaporate or sublimate and escape to the atmosphere as vapour. This vapour is then transported within the atmosphere until such time as changing conditions cause some of it to precipitate or fall back to the earth's surface as rain, snow, or dew. This water, once returned to the surface, can resume its downhill movement until it reaches the oceans or is vaporised once more. This process of ___________ is extremely important as a means of cleansing water of its dissolved substances, which are left behind when the water evaporates.

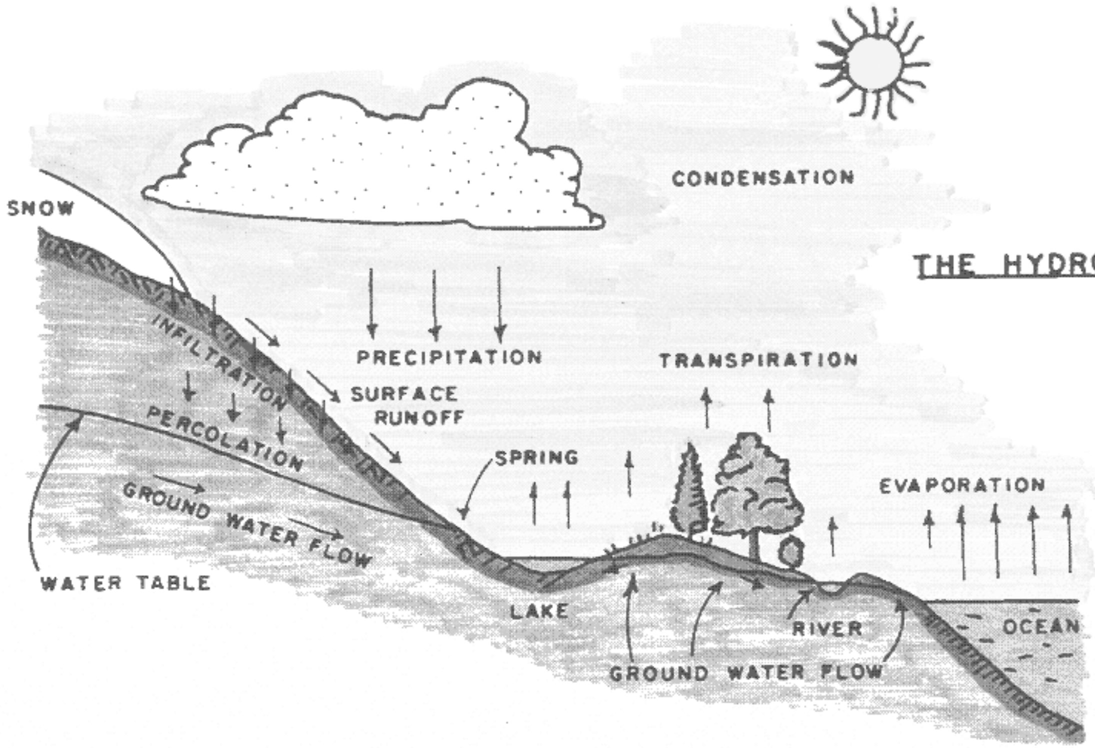


Subheading 7

As human civilizations have developed, many additional uses of water have become important. Some of these uses have resulted in problems both for us and for the earth as a whole. Our challenge it to use water in sustainable ways, such that its use by future generations of humans and other living organisms is not compromised.

With its abundance and its properties as an effective solvent, water has long been used for cleaning and for __________ waste products. We wash in it; we wash our possessions and products with it; we use it to dissolve our unwanted materials and flush them away. Unfortunately, when we have completed our cleaning and waste removal activities, the resulting water is dirty or 'polluted'. When we return water to nature in this state, we are relying on natural processes to cleanse it. We are also passing our ________ on to other users or to other living organisms. These wastes may be toxic to these other living things. The more concentrated these wastes become, the more toxic we can expect them to be. It is estimated that 3 million people die each year from diseases related to water and poor sanitation. Water treatment facilities must be used to remove these wastes before the water is returned to nature. We must then find ways to safely dispose of, or reuse, these so-called 'waste' materials, such that they do not cause adverse ecosystem effects now or in the future.

Humans rely on water to sustain their agricultural crops. Usually, the natural precipitation will be sufficient to water these crops. In other situations, artificial watering systems, usually referred to as irrigation, are used. These irrigation schemes involve modification of the natural water distribution patterns. Sometimes, extra water is drawn from natural groundwater reservoirs far below the soil surface. Other times, rivers are __________ and their waters are diverted through canals to be used on agricultural fields. In the short term, these irrigated croplands can be highly productive. However, any of these diversion schemes have potential long-term consequences for the ecosystems being altered. Often, we have failed to anticipate these problems. Over time, irrigated lands may become saturated with salts from this water, resulting in serious loss of __________ land. The runoff water from agricultural fields may be contaminated by fertilizers or pesticides used to grow and protect the crops. These contaminants may harm downstream ecosystems in a variety of ways.



Water running downhill is an important source of ________. By damming rivers and streams, we have harnessed some of this energy to generate electricity, power machinery, and provide light and heat for our homes and businesses. Done properly, this energy generation should have little polluting effect on the water being used. Dams may also be beneficial to some users by retaining water longer, minimizing extremes of flow, and reducing downstream flooding. However, changing the flow patterns in rivers by damming can have adverse effects on __________ and wildlife which rely on those rivers for their life support. It can also affect the downstream uses of those rivers by other people, and reduce the fertility and productivity of downstream ecosystems which rely on flooding for nutrient input. Creating new reservoirs can flood large areas and may, under certain conditions, lead to pollution of the water. The long term consequences of all these possible effects should be considered when making decisions about the use of water for energy generation.

Water is also used industrially and domestically for transferring heat during various cooling or heating processes. Again, if done properly, this should not result in contamination of the water with pollutants. However, the very act of increasing the water temperature can have adverse effects on ______________ life when this water is discharged to nature. Care must be taken to ensure that such effects are avoided, or at least minimized.

Water, in its liquid form, is a primary medium for heavy __________. Giant ships ply the oceans and large lakes of the world, carrying raw materials and manufactured products. In parts of the earth, waterways were the only practical means of travel for the first settlers who traded with them. These uses of water should be sustainable, provided ships are careful to avoid dumping waste materials, and provided accidents do not result in the spillage of _________ pollutants such as oil. Unfortunately, both of these problems continue to occur all too frequently.

Water is valuable to humans as a recreational resource. We use it for swimming, boating, and fishing. We surf in it, ski on it, splash in it, skate on it and play with it. Again, if done properly, these uses should have minimum impact on its future use and on other users. However, overuse, or careless use, can affect other people and other living things which also rely on this water, both now and in the future.

Subheading 8

Water is so fundamental to our very existence that we must seek to learn how it affects our lives, and how our lives affect it and the other living things that rely on water for their existence. One way to do this is to study the role of water in ecosystems, particularly in aquatic ecosystems where water is so abundant. A better understanding of lake ecosystems can improve our appreciation of the importance of water and the roles it plays in linking us to the world around us. The diagram below presents a simplified view of a typical lake __________.

Energy from the _____ drives this ecosystem, but all the communities shown, the plants on shore, and those humans who use this ecosystem, are linked by the common element, water. Anything affecting the quality or availability of this water will have an impact on the entire ecosystem. However, ecosystems are complex and our understanding of them is incomplete. Often, we are not able to predict in advance exactly what that effect might be.

Subheading 9

Water is an _____________ human need. It is also an invaluable resource to human societies; for cleaning and waste removal, for energy generation, for food production, for cooling and heating, for transportation, and for recreation. Wise use, with a view to the long-term needs of other users, both human and otherwise, can be __________. We must continue to study the role of water in our lives and learn more about the functioning of our ecosystems. Only with better knowledge and understanding can we make wise decisions for water use and management.

Adapted from: http://www.umanitoba.ca/institutes/fisheries/waternot.html

Complete a table with statements of ten properties and ten uses that illustrate the importance of water on the planet Earth.

3-1 Acids and Bases

Acids and Alkalis Notes from *Water Analysis* PowerPoint.

Most people are familiar with many acids and bases found around their homes. But many do not understand the chemistry of these substances and what chemical reactions are involved. This section will help you identify some uses for common acids and bases in the home and laboratory.

Common Acids	Formula	Uses / Sources
Hydrochloric		
Sulfuric		
Nitric		
Ethanoic		
Citric		
Phosphoric		
Carbonic	HCO_3^-	Weak acid in fizzy drinks

Some common properties of Acids

Acids have unique chemical and physical properties.

1. Acids taste ____________________. It is too dangerous to taste unknown liquids to determine if it is acidic.
2. Acids turn litmus _____________ . Litmus is a plant dye extract that changes from red to blue in solutions.
3. Acids have a pH ______________________________
4. Acids are _____________________________
5. They react with ______________________, forming _____________________________
6. They react with ______________________, forming _____________________________
7. React with ___________________________, forming _____________________________
8. React with ___________________________, forming a ____

Bases - Alkalis

Bases are also found in our home. They are often solids but can form aqueous solutions, called _____________.
Alkalis are present in kitchen cleaners like oven spray, floor cleaner and dishwasher detergent.

Common Alkalis	Formula	Uses / Sources
Sodium hydroxide		
Potassium hydroxide		
Calcium hydroxide		
Ammonia		
Sodium hydrogen carbonate		

Properties of Alkalis

Alkalis are soluble bases, and can be thought of as a subset of all bases. Alkalis also have unique chemical and physical properties.

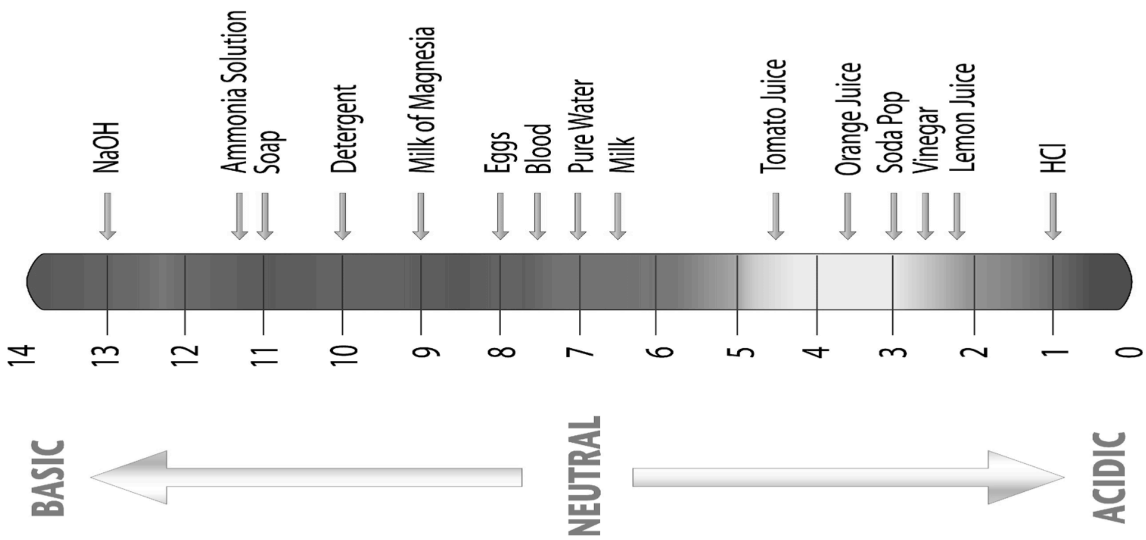
1. Alkalis have ______________________________________
2. Alkalis turn litmus ___________
3. Alkalis have a pH ____________________ than 7
4. Alkalis are ___________________________
5. They have a __________________ feel.
6. They react with acids, forming ____

3-2 The pH Scale

The pH scale is used to determine whether a solution is acidic or alkaline. The scale ranges from 0 to 14.

Neutral solutions measures ____, the median. Strong acids measure about 0-2, _____________________ acids are in the range 3-4 and _________________ acids 5-6.

_______________alkalis measure about 12-14, moderate alkalis are in the range 10-11 and weak alkalis 8-9.



pH Indicators

Plant dyes that change colour in acidic or alkaline solutions are called ______________________. Chemists use these extracts to measure the pH of solutions. For example, litmus is extracted from lichens, and changes colour in solutions. It is used to determine if a solution is acidic or alkaline.

Complete the table by placing the colours of each indicator in the spaces.

Indicator	Colour in acid	Colour in neutral	Colour in alkali
Litmus	Red	Purple	Blue
Phenolphthalein		Colourless	Pink
Methyl orange	Red	Yellow	Yellow
Methyl red		Yellow	
Bromothymol blue	Yellow	Green	

Indicators – Monitoring Change

The pH of solutions can be identified using acid-base indicators; dyes that change colour in the presence of acids or bases. They often change colour over a narrow pH range and are an easy method for chemists to detect the acidity or basicity of a solution. The table shows common indicator colour ranges.

pH Ranges of some Common Indicators

Name of Dye	Colour at Low pH	pH Range	Colour at High pH
Methyl violet	Yellow	0.0 - 1.6	Blue
Methyl orange	Red	3.2 - 4.4	Yellow
Bromophenol blue	Yellow	2.8 - 4.6	Blue
Bromocresol green	Yellow	3.8 - 5.4	Blue
Methyl red	Red	4.2 - 6.3	Yellow
Phenolphthalein	Colourless	8.2 - 10.0	Pink / Violet
Alizarin yellow	Yellow	10.1 - 13.0	Orange

Questions

1. What would be the colour of the following indicators at the assigned pH?

Name of Dye	pH	Colour
Methyl violet	2.5	
Methyl orange	6.4	
Bromophenol blue	1.5	
Bromocresol green	7.0	
Methyl red	4.0	
Phenolphthalein	13.4	
Alizarin yellow	9.5	

2. Indicators are used to test some solutions. Use the table above to identify the pH range of each solution.

Dye	Colour	Dye	Colour	pH range?
Bromocresol green	Blue	Phenolphthalein	Colourless	5.4 – 8.2
Methyl violet	Blue	Methyl orange	Red	
Phenolphthalein	Colourless	Methyl red	Yellow	
Phenolphthalein	Pink / Violet	Alizarin yellow	Orange	
Methyl orange	Yellow	Methyl red	Red	

Teacher Demonstration of Indicator Tests on Common Substances

Your teacher will show some colour changes that identify common acids and bases. The use of litmus paper to identify the presence of acid or base, while Universal indicator can be used to identify pH. Specialist indicators can also be used to determine pH.

The Universal Indicator

Universal indicator is a blend of many dyes to produce a range of colours that change through the entire pH range. It is a useful dye for determining pH. Universal indicator soaked in paper makes a convenient material for pH measurement.

pH of Common Substances

Substance	pH	Acid /Base	Strong/ Moderate/Weak
Sulfuric acid (Car battery acid)	1		
Distilled water, saliva	7		
Conc. sodium hydroxide (Caustic soda)	14		
Black coffee	5		
Tap water	6		
Coca Cola	3		
Ammonia	12		
Tomatoes, grapes, apple juice	4		
Sodium bicarbonate	8		
Toothpaste	9		
Stomach acid	2		
Oven cleaner	13		
Sea water	6		
Dish washing detergent	12		
Lemon juice	2		

3-3 Salts

Any compound that can neutralise an acid is called a base. When acids react with bases, they are said to ________________. Neutralisation always produces a salt … and water. In chemistry, salts are ionic compounds that result from the neutralisation reaction of an acid and a base.

The salts of sulfuric acid are known as *sulfates*:

H_2SO_4 + $2NaOH$ → ________________ + H_2O

The salts of hydrochloric acid are *chlorides*:

HCl + KOH → ________________ + H_2O

The salts of nitric acid are nitrates:

$2HNO_3$ + $Ca(OH)_2$ → ________________ + $2H_2O$

The salts of phosphoric acid are *phosphates*:

H_3PO_4 + $3Mg(OH)_2$ → ________________ + $3H_2O$

Write down the products of the following acid-base neutralisation reactions and balance the equations.

H_2SO_4 + $Ca(OH)_2$ →

HCl + $Mg(OH)_2$ →

HNO_3 + KOH →

3-4 Acid – Base reactions

Acids react with bases in a few, but predictable ways. Common products are salt and water, with carbonates also producing carbon dioxide gas. Here are five types, with examples. Add a second example of each reaction type.

1. Acid + Metal Oxide → Metal Salt + Water

H_2SO_4 + CaO → $CaSO_4$ + H_2O

New example:

2. Acid + Metal Hydroxide → Metal Salt + Water

$2HCl$ + $Mg(OH)_2$ → $MgCl_2$ + $2H_2O$

New example:

3. Acid + Metal Carbonate → Metal Salt + Water + Carbon Dioxide

H_2SO_4 + $ZnCO_3$ → $ZnSO_4$ + H_2O + CO_2

New example:

4. Acid + Metal Hydrogen Carbonate → Metal Salt + Water + Carbon Dioxide

H_2SO_4 + CaO → $CaSO_4$ + H_2O

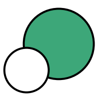
New example:

5. Acid + Ammonia Solution → Ammonium Salt + Water

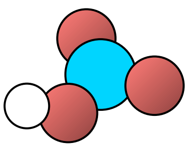
HCl+ NH_4OH → NH_4Cl + H_2O

New example:

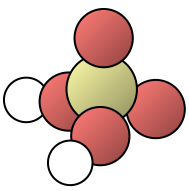
Some common acids



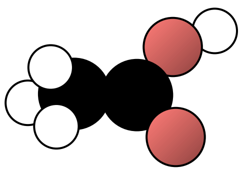
HCl



HNO_3



H_2SO_4



CH_3COOH

Practice makes perfect

Using the examples shown above, write down the products and balance the equations below.

Metal oxides

$2HCl$	+	K_2O	$\rightarrow$
HNO_3	+	Na_2O	$\rightarrow$
H_2SO_4	+	CaO	$\rightarrow$
HCl	+	MgO	$\rightarrow$

Metal hydroxides

$2HCl$	+	KOH	$\rightarrow$
H_2SO_4	+	$Ca(OH)_2$	$\rightarrow$
HNO_3	+	$Zn(OH)_2$	$\rightarrow$
H_2SO_4	+	$LiOH$	$\rightarrow$

Carbonates

HCl	+	K_2CO_3	$\rightarrow$
HNO_3	+	Na_2CO_3	$\rightarrow$
H_2SO_4	+	$CuCO_3$	$\rightarrow$
HCl	+	$ZnCO_3$	$\rightarrow$

Hydrogen carbonates

HCl	+	$KHCO_3$	$\rightarrow$
H_2SO_4	+	$Ca(HCO_3)_2$	$\rightarrow$
HNO_3	+	$Cu(HCO_3)_2$	$\rightarrow$
H_2SO_4	+	$LiHCO_3$	$\rightarrow$

4. For the following reactions:

- Underline the acid
- Place a circle around the base
- Draw a square around the salt

a.	$NaOH$	+	HCl	$\rightarrow$	$NaCl$	+	H_2O
b.	HCl	+	KOH	$\rightarrow$	KCl	+	H_2O
c.	$Ca(OH)_2$	+	HNO_3	$\rightarrow$	H_2O	+	$Ca(NO_3)_2$
d.	H_3PO_4	+	KOH	$\rightarrow$	K_3PO_4	+	H_2O
e.	H_2SO_4	+	$NaOH$	$\rightarrow$	Na_2SO_4	+	H_2O

Spectator ions

In ionic precipitation reactions there are often ions that are not involved in the reaction. These are spectator ions.

$$\mathbf{NaI}(aq) + \mathbf{AgNO_3}(aq) \rightarrow \mathbf{AgI}(s) + \mathbf{NaNO_3}(aq)$$

Spectator ions are easily identified using an ionic equation.

$$\mathbf{Na^{+}(aq) + I^{-}(aq) + Ag^{+}(aq) + NO_3^{-}(aq) \rightarrow AgI\ (s) + Na^{+}(aq) + NO_3^{-}(aq)}$$

This equation shows that only the silver and the iodine ions have reacted, joining together to form the precipitate. The sodium (Na^+) and nitrate (NO_3^-) ions have not changed state and are spectator ions. This means the ionic equation can be simplified to:

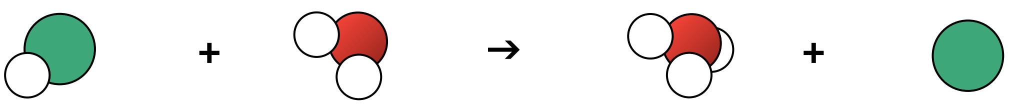
Reaction of hydrochloric acid and water

While these properties help us identify an acid or base, they do not explain what is happening when these substances react. A better explanation (theory) is needed for us to understand the nature of Acid-Base reactions.

Acids are substances that dissolve in water to produce hydrogen ions (H^+). Chemists say that when acids react, they donate H^+ ions (also called protons). Therefore, all acids need to contain hydrogen atoms. If you look at the formulas of H_2SO_4, HCl and HNO_3, you should note that they all contain hydrogen atoms.

The acid donates a hydrogen ion (proton) to the water. Acid-base reactions involve a transfer of hydrogen ions. The acid donates these hydrogen ions, while the base accepts them.

$$\mathbf{HCl + H_2O \rightarrow H_3O^{+} + Cl^{-}}$$



The proton is donated by the hydrogen chloride and accepted by the water… … forming the positive H_3O^+ ion… … and leaving a negative chloride ion.

What is pH?

The pH of a solution is a useful guide to determine the strength of an acidic or basic solution. Chemists define pH as the negative log of the concentration [ ] of the hydrogen ions in a solution:

$$\mathbf{pH = -\log[H^{+}]}$$

This formula can aid chemists in calculating the concentration of solutions, but you will study it in more detail in Year 11 Chemistry.

3-4 Practical 1: The Chemistry of Household Cleaners

2 periods

Aim: To determine the relative Basic concentrations of selected household cleaners. You will write a formal report of this practical.

Chemistry has an important role in the analysis of everyday materials around our homes. We use cleaning agents regularly for the cleaning of benches, sinks, floors, the shower and bath.

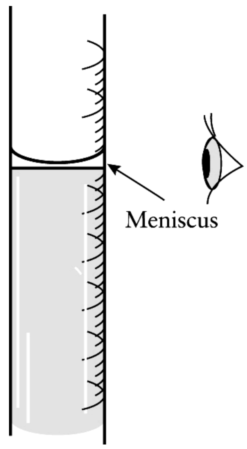
There are three types of household cleaners:

a. Basic (alkaline) – used for removing grease and dirt, these are commonly used on floors.
b. Bleaches / Antibacterial – effective at destroying bacteria, these are used to clean the shower, bath and toilet.
c. Combinations of the Basic and Antibacterial types

In this experiment, you will determine the relative Basic strength of some household cleaners. Bleach will not react with acid, while basic solutions will react. Methyl orange is used an acid-base indicator; it changes from pale yellow in the presence of base to a red in acid.

Equipment:

25mL measuring cylinder	Burette
0.1 M HCl	Household cleaner solutions
3 conical flasks	Methyl orange indicator
250 mL beaker	Funnel

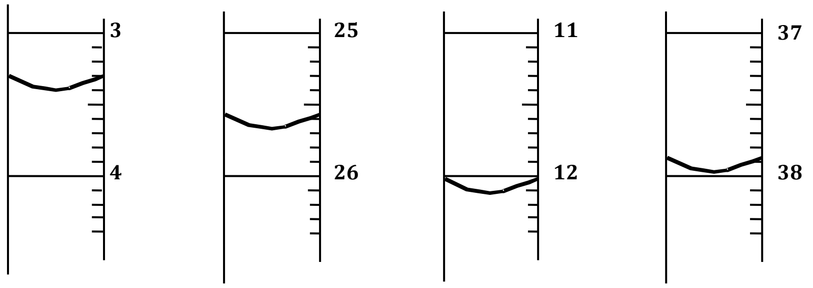


Safety

This experiment involves hazardous chemicals that require goggles and aprons when handling. If splashed on your skin, wash under a tap.

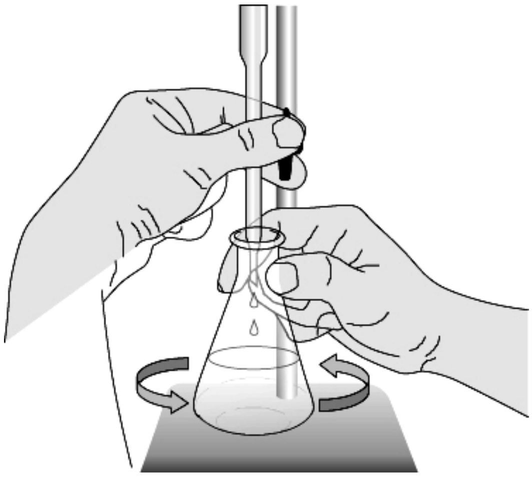
This practical introduces the *burette* to students. This is a high precision instrument that can measure a variable volume of a liquid. With care, it can be read to two decimal places. You will notice that the scale reads from the top down. This scale needs to be read twice: before and after the volume has been delivered. The volume delivered is the difference between the two readings. Precision is achieved through reading the scale from side-on, by reducing parallax error.

1. What are the readings of the burettes below: (*two decimal places*)



Procedure:

1. Place a funnel on top of the burette and carefully fill the burette with the hydrochloric acid solution. Remove the funnel to avoid drips.
2. Using a measuring cylinder, measure 20 mL of a selected cleaner and pour into a conical flask.
3. Add 2-3 drops of of methyl orange indicator to the conical flask.
4. Adjust the burette so that its bottom is slightly inside the conical flask, as shown in the diagram.
5. While swirling the conical flask, add HCl from the burette to the cleaner solution until the indicator just permanently changes colour. This will change to a pink when the acid is in excess. Precision is achieved by conducting this step carefully.
6. Record the volume of HCl added in the Table below.
7. Repeat steps 1-5 and test the remaining cleaners.
8. Determine the rank order of cleaners from most concentrated to least concentrated.
9. Cleanup: All chemicals can be washed down the sink.



Results:

Cleaner Name	Initial Burette Reading (A)	Final Burette Reading (B)	Volume HCl Added (B - A)	Dilution Factor (If concentrated - dilution factor = 1)	Total HCl Volume (HCl Volume × Dilution Factor)
Handy Andy					
Clorox					
Cloudy Ammonia					
Mr. Muscle					
Nifty					
Pine O Clean					

Questions:

1. Why is an acid-base indicator used for this experiment?
2. Explain the reason for Step 4 in the procedure.
3. Why does the solution need to be swirled while adding the acid?
4. Which of your tested cleaners are of the Basic type?
5. Which basic cleaners have the greatest concentration?

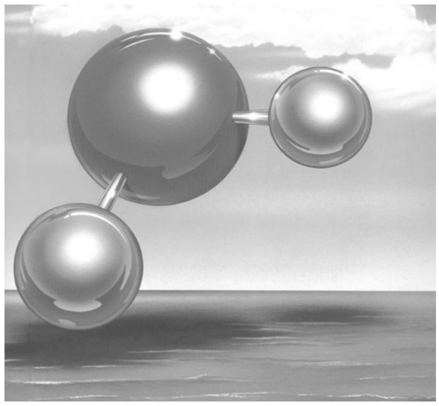
Conclusion / Discussion:

Write a Conclusion and Discussion for this Experiment in your note book.

4-1 Chemical Properties

Molecular Structure

The water molecule contains one oxygen atom bonded to two hydrogen atoms. The molecule is V-shaped. It is a polar molecule, in that it has a positive charge on the hydrogen end and negative charge at the oxygen.



One of the most important properties of water is its ability to dissolve a great variety of substances. This is so effective that water is called the universal solvent. Many chemical reactions that take place in nature involve water as a solvent: fish and plants can live in water because of the presence of dissolved oxygen and carbon dioxide; nutrients are transported around our bodies in water,

4-1 Solubility Trends

The solubility of a substance is the amount that can be dissolved in a fixed amount of solvent. Unfortunately, there is no simple method (such as ionic charge) of predicting if a substance is soluble or not. The only method available is by observing experiments, of which the results are summarised below in the table.

Table: Solubility Trends

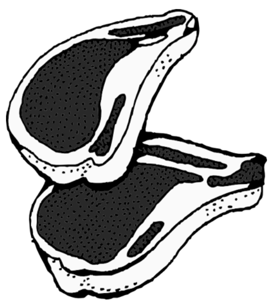
Soluble Compounds

Compounds containing:	Exceptions
Li^+, Na^+, K^+	None
Nitrate (NO_3^-)	None
Ammonium (NH_4^+)	None
Chloride, Bromide, Iodide (Cl^-, Br^-, I^-)	Ag^+, Pb^{2+}
Acetate (CH_3COO^-)	Ag^+
Sulfate (SO_4^{2-})	Ba^{2+}, Pb^{2+}, Ca^{2+}, Ag^+

Insoluble Compounds

Compounds containing:	Exceptions
Carbonate (CO_3^{2-})	Li^+, Na^+, K^+, NH_4^+
Phosphate (PO_4^{3-})	Li^+, Na^+, K^+, NH_4^+
Hydroxide (OH^-)	Li^+, Na^+, K^+, NH_4^+
Sulfide (S^{2-})	Li^+, Na^+, K^+, NH_4^+, Ca^{2+}, Ba^{2+}

Mnemonics (memory aids) to help you learn the solubilities are:



SPANA – compounds of sodium, potassium, ammonium, nitrate and acetate are **always** soluble.

CHOPS – compounds containing carbonate, hydroxide, oxide, phosphate and sulfide are generally insoluble unless combined with SPANA ions.

Questions

1. Which anions are mostly soluble?
2. Which anions are mostly insoluble?
3. Which group(s) on the periodic table produce(s) ions of high solubility?
4. Name the ions that are always soluble.
5. Name the exceptions that are always insoluble.

Which compounds are soluble?

Classify the following compounds as soluble or insoluble in water:

a. Sodium nitrate
b. Potassium phosphate
c. Lead hydroxide

Solution

Refer to the solubility table and identify which ions are present in the compound. Start with the anion (-ve) in the compound.

a. *Sodium nitrate* - The anion is nitrate (NO_3^-). According to the table, all nitrates are soluble in water, with no exceptions. Therefore sodium nitrate is soluble.

b. *Potassium phosphate* - The table lists phosphates as generally insoluble. However, by checking the exceptions lists, we note that potassium is an exception to this rule. So, potassium phosphate is soluble.

c. *Lead hydroxide* – Hydroxides are listed as insoluble, with some cations (+) given as exceptions. Lead (Pb^{2+}) is not on the exception list, and the compound is predicted to be insoluble.

Exercise

Refer to the solubility table and predict the following compounds as soluble or insoluble.

Compound	Formula	Soluble / Insoluble?
sodium bromide		
magnesium hydroxide		
ammonium carbonate		
lead sulfide		
silver chloride		
iron (II) sulfide		
calcium carbonate		
potassium hydroxide		
lead iodide		
aluminium phosphate		
potassium sulfide		
barium sulfate		
lithium carbonate		

4-2 Reading a Solubility Curve

The solubility of a substance is dependent on temperature. The solubility curve shows the number of grams of solute in a saturated solution of 100g of water at a certain temperature. Note the scale of the vertical axis, in grams of solute dissolved in 100g (100 mL) of water.

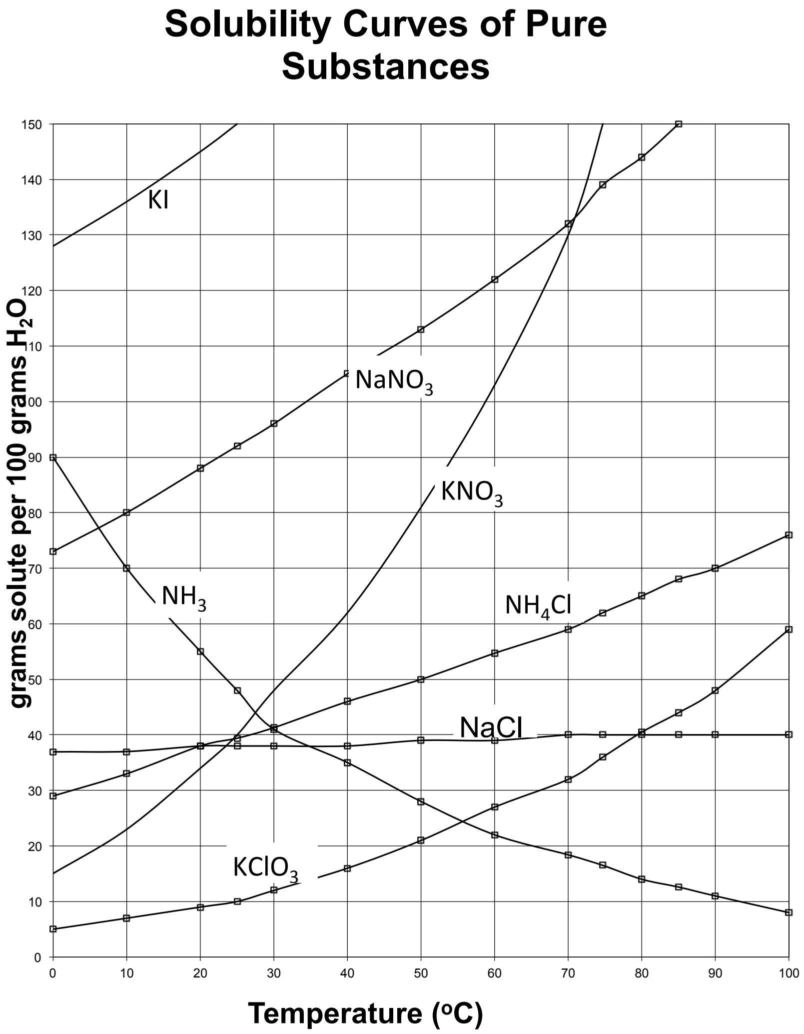
a. Any amount of solute below the line indicates the solution is unsaturated at a certain temperature.

b. Any amount of solute above the line in which all of the solute has dissolved shows the solution is supersaturated.

c. Solutes whose curves move upward with increased temperature are typically solids because the solubility of solids increases with increased temperature.

d. Solutes whose curves move downward with increased temperature are typically gases because the solubility of gases decreases with increased temperature.

e. The volume of 1 mL of water has a mass of 1g. Therefore, 100mL has a mass of 100g, and the units can be used interchangeably.



Strategy to solve solubility problems

1. If the volume of water is 100 mL, then the mass of solute for a saturated solution can be read directly from the graph. e.g. At 10°C, a maximum of 80 g of $NaNO_3$ will dissolve in 100 mL of water.

2. To find the number of grams needed to saturate a solution when the volume is NOT 100 mL use the following strategy:
The amount of solute is needed to saturate a solution at set temp = vol × solubility/100mL

e.g. What mass of sodium nitrate ($NaNO_3$) will dissolve in 60 mL of water?

$$60\text{ mL } H_2O \times \frac{80\text{ g } NaNO_3}{100\text{ mL } H_2O} = 48\text{ g } NaNO_3 \text{ needed to saturate solution}$$

4-3 Solubility Curves Questions

1. Which of the salts shown on the graph is the least soluble in water at 10°C?
2. Which of the salts has the greatest increase in solubility as the temperature increases from 30 degrees to 60 degrees?
3. Which of the salts has its solubility affected the least by a change in temperature?
4. At 20°C, a saturated solution of sodium nitrate contains 100 g of solute in 100 mL of water. How many grams of sodium chlorate must be added to saturate the solution at 50°C?
5. At what temperature do saturated solutions of potassium nitrate and sodium nitrate contain the same mass of solute per 100 mL of water?
6. What two salts have the same amount of solubility at approximately 19°C?
7. How many grams of ammonium nitrate must be added to 1 litre of water to produce a saturated solution at 50°C?
8. A saturated solution of potassium nitrate is prepared at 60°C using 100 mL of water. How many grams of solute will precipitate out of solution if the temperature is suddenly cooled to 30°C?
9. If 50 mL of water that is saturated with $KClO_3$ at 25°C is slowly evaporated to dryness, how many grams of the dry salt would remain?
10. 30 g of KCl is dissolved in 100 mL of water at 45°. What extra mass of KCl needs to be added to make the solution saturated at 80°C?
11. What is the smallest volume of water, in mL, required to completely dissolve 46 grams of KNO_3 at 10°C?
12. What is the lowest temperature at which 30 g of KCl can be dissolved in 100 mL of water?
13. Are the following solutions saturated, unsaturated or supersaturated?
    a. 40g of KCl in 100 mL of water at 80°C
    b. 120g of KNO_3 in 100 mL of water at 60°C
    c. 80g of $NaNO_3$ in 100 mL of water at 10°C
    d. 20g NaCl in 50 mL of water at 30°C
    e. 12g NH_4Cl in 20 mL of water at 60°C
    f. 22g $NaNO_3$ in 25 mL of water at 20°C
14. Assume that a solubility curve for a gas such as ammonia, NH_3 was plotted on the solubility curve graph. Reading from left to right, would this curve would _____
    a. slope upward b. slope downward c. be horizontal

4-4 The Universal Solvent

Water is called the *Universal Solvent*. As a polar solvent, it will dissolve many substances found in nature and therefore often contains substances other than water particles. Even rainwater has gases and other solids dissolved in it before its reaches the ground. Rain flushes airborne dust and pollution around our cities.

Type of Water	Total solids (mg/L)
Rain	29.5
Surface runoff	97
Deep Well	438
Spring	282

The amount of dissolved solids in rainwater depends on the location of the rainfall. Southern Victoria has a value of about 10 mg/L of salt, while Northern Victoria has readings of 1–2 mg/L. This adds up to approximately 20 kg of salt falling on a hectare of land every year.

Seawater has considerable amounts of dissolved salts. If an Olympic-sized pool were filled with seawater, the amounts of the main elements present would be as shown in the table.

Element	Amount (kg)
Chloride	**37 500**
Sodium	**20 000**
Magnesium	**2 500**
Sulfate	**1 700**
Calcium	**800**
Potassium	**750**
Bromide	**130**
Carbonate	**54**
Silicate	**6**
Fluoride	**3**

1. What is the most common substance found in seawater?

2. What is the *total mass* of dissolved solids in an Olympic-sized pool?

3. There are many carbonates found on Earth, yet very little in seawater. What does this indicate about the solubility of carbonates?

4. Why does water obtained from deep wells have more dissolved solids than rainwater?

4-5 Precipitation Reactions

Sometimes when solutions are mixed, an insoluble white or coloured solid is observed. This product can sink to the bottom or remain suspended in the solution and is called a precipitate. These precipitation reactions occur when two soluble compounds are mixed to form an insoluble product and usually involve an exchange of ions.

Example

For example, when clear solutions of potassium iodide and lead nitrate are mixed, a dense yellow precipitate appears. This precipitate is solid lead iodide, with a solution of potassium nitrate. The word and full equations for this reaction are:

lead nitrate + potassium iodide → lead iodide + potassium nitrate

$Pb(NO_3)_2\ (aq) + 2KI\ (aq) \rightarrow PbI_2\ (s) + 2KNO_3\ (aq)$

Precipitation reactions involve an exchange of ions. In the above example, the lead combines with the iodide ions to form lead iodide and the potassium and nitrate ions form a solution of potassium nitrate. The reaction states in brackets (s, l, g or aq) indicate the state of each reactant and product.

To investigate this reaction further, let us look once again at the solubility trends in the table on page 24 and link this to the reaction states.

According to the solubility table:

Compound	Soluble / Insoluble	Explanation
lead nitrate	Soluble	All nitrates are soluble
potassium iodide	Soluble	Iodides are soluble except Ag^+, Pb^{2+}
lead iodide	Insoluble	Iodides are soluble except Ag^+, Pb^{2+}
potassium nitrate	Soluble	All nitrates are soluble

Therefore the yellow solid produced must be the insoluble lead iodide.

Method of problem solving

To predict if a precipitate forms when two aqueous solutions are mixed, we need to:

1. Identify the ions present in the reactants of both solutions.
2. Consider the possible combinations of cations and anions when mixed.
3. Refer to the solubility table on page 24 to determine if any combinations are soluble or insoluble.
4. If no combinations produce an insoluble substance, then no reaction occurs.

Precipitation Exercise

1. Predict if the following reactions will form a precipitate, and if so, give the complete equation. Underline the solid produced. If no precipitate forms, write *No Reaction*.

Reactants			Equation
$MgCl_2$	+	$AgNO_3$	
$NaBr$	+	$Pb(NO_3)_2$	
$Mg(NO_3)_2$	+	NaI	
$CuSO_4$	+	$NaOH$	
$(NH_4)_2CO_3$	+	$Fe(NO_3)_2$	
$Ba(NO_3)_2$	+	Li_2SO_4	
$ZnSO_4$	+	K_2S	
K_3PO_4	+	$Pb(NO_3)_2$	
$NaNO_3$	+	K_2SO_4	
KI	+	$NaCl$	
Na_2CO_3	+	$CaCl_2$	

Exchange Reactions

2. Complete the following reactions, where the ions are exchanged in solution:

iron nitrate + ______________ → iron hydroxide + potassium nitrate

sodium sulfate + barium nitrate → sodium nitrate + ____________

silver nitrate + zinc chloride → ____________ + ______________

lead nitrate + magnesium chloride → magnesium nitrate + ____________

5-2 Practical 2: Flame Tests

1 period

Introduction

Fireworks rocket displays are enjoyable parts of our celebrations, such as on New Year's Eve. Fireworks (and gunpowder) were probably invented by the Chinese and introduced to the West by Marco Polo in 1292. The dazzling colours of fireworks are due to metal compounds becoming vaporised and excited at high temperatures, emitting characteristic colours.

Chemical flame tests use the same principles and can be used to determine what cations are present in an unknown sample. When atoms or ions are heated in a flame, some electrons may absorb enough energy to allow them to *jump* to higher energy levels. These excited state electrons are unstable and they will *fall back* to their normal positions of lower energy. As the electrons return to the ground state, the energy that was absorbed is emitted in the form of visible light and we see colour. Since every element has its own arrangement of electrons, each metal produces a unique flame colour. However, not all metals produce a distinct flame colour.

Safety

This practical involves heating hazards. Wear goggles and aprons. Care should be taken when handling hot items. Bench mats are to be used in this experiment.

Aim

To observe the characteristic colours produced by certain metallic ions when vaporized in a flame
To identify an unknown metallic ion by means of its flame test.

Materials

Wooden splints Bunsen burner
1M Solutions: Chlorides of Li^+, Na^+, K^+, Ca^{2+}, Cu^{2+}, 0.1M Ba^{2+},
Beaker half-filled with water

Procedure

1. Put on safety goggles and aprons.
2. Half fill a beaker with water to deposit and extinguish used wooden splints.
3. Set up the Bunsen burner on the heatproof mat.
4. Place a wooden splint into a metallic ion solution and let it soak for 10 seconds. Remove it and insert into the Bunsen flame. Observe the colour produced by the ion and record the colour in Table 1.
5. Repeat for all ion solutions.
6. Now test each sample of unknown solutions. Perform a flame test and identify the metallic ion present by the colour of the flame. Record your results in Table 2.
7. Write a Conclusion for this experiment.
8. Clean up your lab bench.

Uses of Flame Tests

Flame tests are useful techniques for confirming the results of a precipitate test. For example, an unknown solution that produced a pale blue precipitate with sodium hydroxide solution, and a green-blue flame test, must contain a copper compound. Note: aluminium, magnesium, iron and zinc do not produce useful identifying flame colours.

To identify an alkali metal, a flame test must be used instead of a sodium hydroxide precipitate test. This is because the alkali metals do not form precipitates with sodium hydroxide.

Teacher Demonstration

Your teacher will spray some flammable solutions into a flame. Identify the elements present by flame colour.

Table 1: Student Results

Metal ion	Colour in flame
Na^+	
K^+	
Li^+	
Ca^{2+}	
Cu^{2+}	
Ba^{2+}	

Table 2: Teacher demonstration of Unknowns

Unknown ion	Colour in flame
A	
B	
C	
D	
E	
F	

Conclusion

5-3 Practical 3: Qualitative Analysis of Cations

2 periods

Introduction: The Role of Chemical Analysis

Chemists are often employed in identifying chemicals present in samples – from foods to water pollutants. They can use their knowledge of reactions to identify positive cations or negative anions present in a water sample.

During a chemical analysis scientists aim to identify an unknown substance. Reacting it with a range of different substances achieves this. The substance is identified by characteristic reactions, such as those that produce a colour or precipitation change.

A **qualitative analysis** determines what substances are present. It obtains non-numerical information about a substance and its properties. **Quantitative analysis** measures how much of a substance is present, and is measured. In this experiment you will encounter the standard tests used to find out what ions are present in unknown solutions. These experiments are part of a classical analysis scheme developed by chemists of past generations to identify unknowns.

Aim: To test the presence of selected cations in solutions
To observe the standard tests to identify these cations

Materials

Solutions (0.5M) of NH_4Cl, NH_4NO_3, (0.1M) of $Cu(NO_3)_2$, $FeSO_4$, $FeCl_3$, $Pb(NO_3)_2$, $AgNO_3$, $Ba(NO_3)_2$

Test reagents – *marked with Red Dot:* (0.1M): KSCN, $K_3Fe(CN)_6$, KI, Na_2SO_4 , NaCl; NaOH(1M), NH_3(1M)

Wooden test tube holders
Test tubes
Red Litmus paper
Bunsen burner
Matches
Forceps

! Safety

Goggles and aprons are to be used at all times during this experiment. If chemicals are splashed on your skin, wash under running water.

A. Identification of the ammonium ion, NH_4^+

Salts of ammonium ions are extremely soluble in aqueous solutions. Therefore, whenever possible, determination of the presence or absence of ammonium ion should be done at the beginning of a qualitative analysis scheme. This will allow you to use ammonium salts as reagents whenever possible without affecting your results.

1. Pour 1 mL (1 cm depth) of ammonium chloride solution into a test tube. Add 5 drops of 1M NaOH to the solution.
2. Wet a piece of red litmus paper with water and place the litmus paper across the top of the test tube.
3. Warm the solution by heating the slowly over a Bunsen burner. (Do not boil the solution.)
4. Observe any change to the litmus paper, and carefully waft some fumes to identify the evolved fumes.
5. Repeat the test with ammonium nitrate. Record your results in the table.

Cation	Test	Observations
NH_4^+ (NH_4Cl)	NaOH	
	Litmus	
NH_4^+ (NH_4NO_3)	NaOH	
	Litmus	

B. Identification of metal ions

Some metal ions can be identified by flame tests. However, precipitation reactions can also be used to identify these positive ions, as many metals form hydroxide precipitates with characteristic colours. There are a few tests used to identify metal ions, and this method uses hydroxide or ammonia. You may see a jelly-like substance form in some of these reactions, described as a *gelatinous precipitate*.

Silver-Ag^+, Lead- Pb^{2+}, Copper- Cu^{2+}, Iron(II)- Fe^{2+}, Iron(III)- Fe^{3+}, Barium- Ba^{2+}

1. Pour 1 mL of copper nitrate ($Cu(NO_3)_2$) solution into a test tube. Add 5 drops of 1M sodium hydroxide (NaOH) to the solution.
2. Observe any precipitate formed. A small amount of precipitate may turn the mixture cloudy, while more may be described as milky. Some precipitates remain in suspension, while other more dense forms will settle to the bottom. Record your observations in the table.
3. Pour 1 mL of copper nitrate ($Cu(NO_3)_2$) solution into a test tube. Add 5 drops of 1M ammonia (NH_3) to the solution. Record your observations in the table.
4. Repeat the test using all the metal ions in the list: Ag^+, Pb^{2+}, Cu^{2+}, Fe^{2+}, Fe^{3+}, Zn^{2+}, Ba^{2+}. Record your results.

Tests to confirm specific ions

Iron(II) and Iron(III)

5. Add 1 mL of iron (II) sulfate solution into another test tube. Add 5 drops of 1M NaOH to this solution and record your results in the table.
6. To distinguish Fe^{2+} from Fe^{3+}, add 2 drops of potassium hexacyanoferrate(III), $K_3Fe(CN)_6$, to 1 mL of iron (II) sulfate.
7. Add 2 drops potassium thiocyanate (KSCN) to 1 mL of iron (III) nitrate. Record both results.

Lead- Pb^{2+}

1. Add 1 mL of lead nitrate solution into a test tube. Add 5 drops of potassium iodide to the solution.
2. Record your results in the table.

Cation	Test	Observations
Cu^{2+} $Cu(NO_3)_2$	NaOH	
	NH_3	
Ag^{+} $AgNO_3$	NaOH	
	NaCl	
Ba^{2+} $Ba(NO_3)_2$	NaOH	
	SO_4^{2-}	
Fe^{2+} $FeSO_4$	NaOH	
	$K_3Fe(CN)_6$	
Fe^{3+} $FeCl_3$	NaOH	
	KSCN	
Pb^{2+} $Pb(NO_3)_2$	NaOH	
	KI	

5-4 Practical 4: Qualitative Analysis of Anions

3 periods

Following on from the previous experiments on cations, this practical class involves using further chemical tests to identify the negative ions present in solutions – the anions.

Materials

(0.1M) $AgNO_3$, NaCl, NaBr, KI, limewater ($Ca(OH)_2$), $BaCl_2$, Na_2SO_4, NH_4SO_4, NaI
Test reagents – *marked with yellow dots* : (1M) HNO_3, HCl, acidified $BaCl_2$
Phenolphthalein,

Solids

$CaCO_3$, Na_2CO_3,

Teacher Demonstration

1M NaOH, NH_4Cl, 0.1M KOH, Na_3PO_4, $NaNO_3$, acidified $(NH_4)_2MoO_4$,
Al powder, red litmus paper, test tube holder

Safety

Goggles and aprons are to be used at all times during this experiment. If chemicals are splashed on your skin, wash under running water.

Equipment

Test tubes, test tubes with side-arms, matches

A. Identification of Halides – chloride (Cl^-), iodide (I^-) and bromide (Br^-) ions

The halides are ions of Group 7 elements: fluoride, chloride, bromide and iodide. They are usually soluble in water, but form insoluble compounds with the silver ion. Fluoride is soluble and produces no precipitate. The other three will form precipitates, but can be distinguished from one another by their colour differences. Sodium chloride, table salt, is commonly found in waterways, especially saline waters near oceans.

1. Pour 1 mL (1 cm depth) of sodium chloride solution into a test tube. Add 2 drops of 1M HNO_3 solution then 5 drops of silver nitrate solution. Carefully observe any colour change.
3. Repeat the test with sodium iodide and sodium bromide.
4. Compare the colours of the observed precipitates formed and record your results.

Anion	Test	Observations
Cl^- (NaCl)	$AgNO_3/HNO_3$	
Br^- (NaBr)	$AgNO_3/HNO_3$	
I^- (KI)	$AgNO_3/HNO_3$	

Equations:

$Ag^+_{(aq)} + Br^-_{(aq)} \rightarrow$

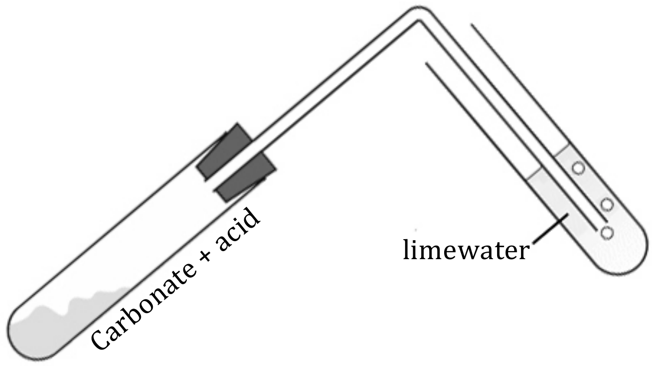
$Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow$

$Ag^+_{(aq)} + I^-_{(aq)} \rightarrow$

B. Identification of Carbonate – CO_3^{2-}

Carbonate is the anion present in limestone as calcium carbonate. Carbonate ions are also found in common household products such as of baking soda. Most carbonates are insoluble in water, except for sodium, potassium, lithium and ammonium. Carbonates are slightly basic and will turn phenolphthalein pink.

Carbonates are relatively easy to identify since they react with acids. The test shown here is a standard way to identify this anion.



1. Place 3 mL of limewater ($Ca(OH)_2$) in a test tube. This will be used to collect and test any gas evolved during the next step. Connect the equipment as shown in the diagram.
2. Place a spatula of solid calcium carbonate into a test tube. Add 1mL of 1M HCl solution and observe any reaction.
3. Collect any gas evolved by bubbling it through the limewater, and observe any changes to the limewater. Observe and record these changes.
4. What gas is limewater used to indicate the presence of? ______________________

Anion	Test	Observations
CO_3^{2-} ($CaCO_3$)	**HCl**	
	Limewater	
CO_3^{2-} (Na_2CO_3)	**HCl**	
	Limewater	

Complete the equations:

magnesium carbonate + hydrochloric acid → magnesium chloride + carbon dioxide + water

Na_2CO_3 (aq) + HCl(aq) →

NH_4CO_3 (aq) + HCl(aq) →

potassium carbonate + hydrochloric acid →

copper carbonate + hydrochloric acid →

C. Identification of Sulfate – SO_4^{2-}

Sulfate ions (SO_4^{2-}) can be identified by adding a few drops of barium chloride solution. The solution must be acidified first with a few drops of nitric acid. This acid reacts with any carbonate that could be present to prevent its precipitation, giving a false positive result.

1. Pour 1 mL of sodium sulfate solution into a test tube. Add 1 drop of 1M HNO_3 solution then 5 drops of barium chloride solution. Observe any changes and record results in the table.
2. Repeat the test with ammonium sulfate.

Anion	Test	Observations
SO_4^{2-} (Na_2SO_4)	**$BaCl_2/HNO_3$**	
SO_4^{2-} (NH_4SO_4)	**$BaCl_2/HNO_3$**	

4. Write balanced equations for the reactions:

Na_2SO_4 (aq) + $BaCl_2$(aq) →

$(NH_4)_2SO_4$ (aq) + $BaCl_2$(aq) →

potassium sulfate and barium chloride solutions

zinc sulfate and barium chloride solutions

Teacher Demonstrations

D. Identification of Nitrate – NO_3^-

The nitrate ion (NO_3^-) can be identified by heating the solution with aluminium powder and sodium hydroxide solution.

1. Pour 1 mL of sodium nitrate solution into a test tube. Add 5 drops of 1M NaOH solution and half a spatula of fine aluminium powder.
2. Heat the mixture gently over a Bunsen burner. This may take a few minutes to react.
3. Carefully smell any gas by gently wafting it near your nose.
4. Hold a piece of damp red litmus paper over the mouth of the test tube and note any colour change.

Equation for identification of nitrate: (on PowerPoint)

E. Identification of Hydroxide – OH^-

In the previous practical you observed a test for ammonium ions by reacting it with sodium hydroxide. This reaction can be used in reverse by adding a solution of ammonium chloride to hydroxide ions. Acids react with bases to produce an ionic salt and water. Bases turn litmus paper blue.

1. Place 1 mL of sodium hydroxide in a test tube.
2. Add 5 drops of ammonium chloride to the test tube and warm over a Bunsen burner. Very carefully note the smell of any gas evolved.
3. Hold a piece of moist red litmus paper over the top of the test tube and test the evolved gas.
4. Record all results in the table below.
5. Repeat the tests using potassium hydroxide.

Anion	Test	Observations
OH^- (NaOH)	**NH_4Cl**	
	Litmus	
OH^- (KOH)	**NH_4Cl**	
	Litmus	

Equation for the identification of hydroxide: $NH_4^+{}_{(aq)} + OH^-{}_{(aq)} \longrightarrow NH_{3(g)} + H_2O_{(l)}$

F. Phosphate – PO_4^{3-}

The phosphate ion is commonly found in laundry detergent and fertilisers. One of the nutrient ions, it promotes plant growth.

1. Take a tiny amount of sodium phosphate solution, and add 4 drops of ammonium molybdate - $(NH_4)_2MoO_4$ solution in a clean test tube.
2. Warm the test tube over a Bunsen burner and observe any colour change.

PO_4^{3-} (Na_3PO_4)	**$(NH_4)_2MoO_4$**	

5-5 Summary Identification of Ions Tests

Positive Cations

Cation	Test	Observation
Fe^{2+}		
Ag^{+}		
Cu^{2+}		
Na^{+}	Flame test	
NH_4^{+}	Add OH^{-}	
Fe^{3+}	Add KSCN	

Negative Anions

Anion	Test	Observation
OH^{-}		Turns blue
Br^{-}		
NO_3^{-}	Warm with Al / NaOH	
Cl^{-}		
SO_4^{2-}	Add $BaCl_2/HNO_3$	
PO_4^{3-}	Add $(NH_4)_2MoO_4$	

5-6 Qualitative analysis

Qualitative analysis tells us what substances are present in a sample. It obtains non-numerical information about a substance and its properties. Quantitative analysis tells us how much of a substance is present in a sample. It is measured, and is expressed in units such as mass (g) or concentration (M). Both can be used to identify an unknown substance. In general, ________________________________ tend to be qualitative, while instrumental techniques tend to be quantitative.

Modern chemists tend to use ______________________________ to identify compounds, as they are very accurate and preserve the original sample, unlike chemical techniques. In this unit, you will encounter both analyses types.

How to perform qualitative analysis

Chemical tests can be split into two groups:

General tests – these help you to identify the ______________________of the chemical. e.g. acid or alkali? Is it soluble? Is it ionic?

Specific tests – these identify the ____.

General tests should be used early in your analysis. They should be informative and help to narrow down your search. A specific test should be ___________________ for that substance to prevent confusing results.

Qualitative tests

There are some chemical tests used to identify ions in solutions.

Cations: mostly metallic	Anions: non-metallic
Flame colours: Flame colours: Li, Na, K, Ba, Ca, Cu	Carbonate ions
Ammonium ions (not metallic)	Nitrate ions
Iron(II) and iron(III)	Sulfate ions
Lead, silver, copper and zinc	Halide ions
	Phosphate ions

Water Analysis

An insoluble solid that forms during an aqueous reaction is called a ______________________. A reaction that forms a precipitate is called a precipitation reaction.

The limewater test for carbon dioxide is a precipitation reaction. When CO_2 is bubbled through limewater, it turns ______________________. Limewater is actually a dilute solution of calcium hydroxide.

The calcium hydroxide reacts with carbon dioxide to form calcium carbonate, which is insoluble in water:

Equation:

Identifying metal ions

There are some chemical tests used to identify metal ions in solutions. Metals can be tested with the addition of the hydroxide ion to observe the colour of the precipitate formed.

Metal	Formula	Metal	Formula
Silver		Iron(III)	
Lead		Zinc	
Copper		Barium	
Iron(II)			

Flame tests – metals

Flame colours are used to identify some metals. Colours are produced from the movement of the electrons in the metal ions present in the compounds. Every metal has a unique colour. Place the flame colours of the ions below:

Metal	Flame Colour
Barium	
Calcium	
Copper	
Lithium	
Sodium	
Potassium	

Which metal hydroxide?

Metal hydroxide	Colour of precipitate
Iron (II)	
Iron (III)	
Copper (II)	
Lithium	
Sodium	
Potassium	

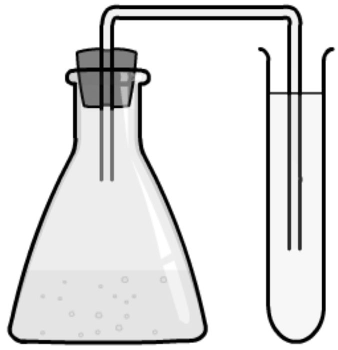
Identify these nitrate compounds

Cation	Test	Observation
	Add HCl	White ppt
	Add H_2SO_4	White ppt
	Flame Test	Lilac colour
	Litmus	Blue turns red
	NaOH	Rusty red gelatinous ppt
	Heat the solution with sodium hydroxide solution	Smell of ammonia
	Flame Test	Brick red colour

5-7 Tests for Anions

Identifying carbonate ions

Carbonates, which contain the CO_3^{2-} ion, are identified by the addition of a few drops of dilute hydrochloric acid. A colourless gas is given off as the carbonate ions react with the hydrogen ions.



The equation for this reaction is:

How would you check the identity of the gaseous product? ____________________
____

What are the other products of this reaction? ____
____

Identifying nitrate ions

The nitrate ion (NO_3^-) can be identified by heating the solution with aluminium powder and sodium hydroxide solution. The aluminium reduces the nitrate ion to ammonia on heating. This is released ____________________ and can be easily identified.

$$3NO_3^-(aq) + 8Al(s) + 5OH^-(aq) + 18H_2O(l) \rightarrow 3NH_3(g) + 8Al(OH)_4^-(aq)$$

How could you confirm that the gas given off is ammonia? ____
____

Identifying sulfate ions

Sulfate ions (SO_4^{2-}) are identified by adding a few drops of barium chloride solution. The solution must be acidified first with a few drops of hydrochloric acid. This is to prevent the precipitation of any carbonate.

A white precipitate of barium sulfate forms.

sodium sulfate + barium chloride $\rightarrow$ barium sulfate + sodium chloride

Equation:

Identifying halides

Halide ions are formed from the Group VII elements, the halogens. Halides are detected using silver nitrate solution. The substance to be tested is first acidified with a small amount of nitric acid before adding the silver nitrate solution.

If halides are present, a precipitate will form. The precipitates formed are silver halides:

sodium chloride + silver nitrate → silver chloride + sodium nitrate

Write the equations for the reaction of silver nitrate and each of sodium bromide and iodide.

Test for hydroxide

Hydroxides are the active component of basic solutions. They are easily identified by using litmus.

Hydroxides have ______________________________. They turn litmus ______________________________.

Identifying phosphate ions

Phosphate ions are detected using acidified ammonium molybdate, which produces a bright yellow precipitate. This is a specific test for phosphate, and is used to confirm its presence. The reaction is complex, which forms a compound with a large structure.

sodium phosphate + ammonium molybdate → phosphomolybdic acid