NELSON CHEMISTRY

Context 1: Matter in the universe

CHAPTER SUMMARY

- **Elements** up to iron in the periodic table are **formed** during the **life cycle** of **massive stars**. **Heavier elements** are formed when **stars** die and **explode** in a **supernova**. Scientists can **synthesise elements** not found naturally on earth.
- **Light** from the stars and **techniques** such as **spectroscopy** are used to **learn** about the **stars**. Elements have **unique emission spectra**, so scientists can determine the **elemental composition** of a star by **examining** the **light** that it emits.
- Scientist **organise** elements on the **periodic table** to show **patterns** and **trends**. Developed after scientists noticed **patterns** in the **physical** and **chemical properties** of elements.
- Scientists **analyse** materials by **different techniques** to **identify** elements present and to **measure** the **quantities** of those elements. Analysis of elements can **provide information** about **health problems** and the **quality** of **our** food, and help solve **crimes**.
- Elements in their **pure form** are useful in a wide variety of applications from **electronics** to **medicine**. Elements such as silicon, titanium and some elemental gases are used in semiconductors, solar panels, structural materials and signage.
- **Nanotechnology** deals with the **behaviour** of **materials** that has very **small particles**. **Carbon nanotubes** have extremely **high strength-to-weight properties**, makes them useful in medicine, textiles and materials science. **Colloidal** gold is used widely in medicine because it can **attach** to specific **cells** and be **targeted** by **light** sources.
- **Isotopes**, both stable and unstable, are useful because of their **differences** from other isotopes of the same element. Isotopes form **naturally** and **artificially** when the **nucleus** of an existing element is **changed** through **fission**.
- **Radioactive** isotopes **emit radiation** that can be **detected** and **measured**. Used to **diagnose** and **treat illnesses** such as cancer. Risk of damage due to isotope exposure is minimised through strategies such as **reducing exposure** and using isotopes with **short half-lives**. Stable isotopes that don’t emit radiation are used in some procedures involving high-risk groups.

CHAPTER GLOSSARY

- **Actinoids/ Lanthanoids** - the period of the periodic table that make up the f block
- **Big Bang** - the rapid expansion of matter from a high temperature and density state at the origin of the universe
- **Black hole** - a region of space with extremely high gravitational field in which light and matter can't escape
- **Chromatography** - the techniques used to seperate components of aqueous, liquid or gaseous mixtures
- **Colloid** - a mixture in which tiny clusters of particles dispersed through another substance; don't settle out due to gravity, particles too small to be filtered
- **Diatoms** - single-celled algae found in water sources
- **Emission spectrum** - a pattern of bands produced by the emission of light from a source, separated due to the different wave lengths present
- **Half life** - the time taken for radioactive emissions of an isotope to fall to half the original value
- **Main sequence** - stars that are in a state of equilibrium between gravity and the pressure produced by nuclear fusion
- **Nano material** - a substance that is made of or incorporate nano particles, with unique properties
- **Nano particle** - a particle that is on the nanometre (one billionth of a metre) scale (10^{-9}m)
- **Nano technology** - a branch of science dealing with particles in the range of 1-100nm
- **Neutron star** - a celestial body composed of neutrons, with high density and strong magnetic field, formed after the death of a massive star
- **Qualitative analysis** - analysis that identifies an element or substance, doesn't make numerical measurements about it, such as mass or concentration
- **Quantitative analysis** - analysis that measures values such as amount, concentration or volume rather than just identifying the substance
- **Radioactive decay** - the spontaneous disintegration of an atom due to instability in the nucleus, releasing particles or electromagnetic radiation
- **Red giant** - a star in the late stage of its life cycle, not undergoing hydrogen fusion, with high luminosity but low temperature
- **Red supergiant** - a massive star that is undergoing helium fusion, with low temperatures and extremely large radii
- Semiconductors - a substance that has little to no electrical resistance when cooled to extremely low temperatures
- **Spectroscope** - a device used to seperate light into its component wavelengths
- **Supernova** - the explosion of a star at the end of its life cycle, resulting in the ejection of most of the star's mass
- **Synthetic element** - an element that doesn't exist in nature, but has been made in a laboratory
- **White dwarf** - a planet-sized, dense star formed when a small star ceases nuclear fusion

Context 2: Materials for a purpose

CHAPTER SUMMARY

- Humans have been looking for materials with **specific properties** to use for **specific purposes** for thousands of years. This began with very **primitive material** in the **Stone Age** and then became more **advanced** as processes were developed to **extract metals** from **ores** during the **Bronze Age** and **Iron Age**.
- Some natural materials are useful with minimal processing; for example, marble, wool and cotton. However, many materials need to be **processed** to be **useful**; for example, fuels. These materials can **undergo physical** and **chemical processes** to make them **useful**.
- Most elements are very **reactive** so are **found naturally in compounds**. The more **reactive** elements require **more technologically advanced** methods to **extract** them from their compounds.
- **Mining** is a major industry in Australia, which involves **large-scale operations** of **physical** and **chemical processes** to **extract** the **metal** from its **ore**. Uranium mining is one such example. Before a mining operation is established, many **economic**, **social**, **cultural**, **environmental** and **ethical issues** need to be **considered**.
- A deep understanding of the **properties** of different elements has **enabled processes** to be **developed** for **isolating specific rare earth elements** from **ores**. This has enabled the development of new technologies, such a stronger magnets and batteries for hybrid vehicles.
- Humans are becoming more conscious of their **impact** on the environment. **Recycling** is one way of minimising this impact. Chemists are also developing **new materials** from **renewable resources**; for example, crops being used to produce green gasoline and biodiesel. Renewable fuel must have **similar properties** and uses as existing fuels from non renewable sources.
- Chemist are continually developing **new materials**. They are **analysing** materials in nature to develop new materials, such as Geckskin in Shrilk.

CHAPTER GLOSSARY

- **Alloy** - a mixture of two or more elements, one of which must be a metal
- **Catalytic cracking** - the chemical process of breaking longer chain hydrocarbons into shorter chain hydrocarbons
- **Chelating ligand** - a covalent substance whose molecules can form several bonds which each single metal ion
- **Combustion** - a reaction with oxygen to form the oxides of each of the element present; with adequate oxygen, combustion of a hydrocarbon will produce carbon dioxide and water.
- **Corrosion** - a chemical reaction in which a metal degrades in the presence of oxygen and water to form the oxide of the metal.
- **Covalent compound** - a compound composed of atoms of at least two different non-metals chemically combined in definite Proportions
- **Eluting** - separating the parts of a mixture by using the property that they travel through a solvent at different rates
- **Environmental footprint** - a measure of the impact of humans on Earth's ecosystems and resources
- **Flashpoint** - the lowest temperature at which a fuel has enough vapour present to ignite in air
- **Hydrocarbon** - a chemical compound composed only of carbon and hydrogen
- **Volatile** - Can change from a liquid to a gas (vaporise) easily.
- **Zeolite** - an aluminosilicate material; i.e. contains Al, Si and O

Context 3: Water, the vital substance

CHAPTER SUMMARY

- Water has unique properties that are **vital** to the **biological**, **chemical** and **physical processes** on Earth. Water exists naturally in three states: **Solid** (ice), **liquid** (oceans, lakes and rivers) and **gas** (water vapour).
- **Strong hydrogen bonding** in water accounts for all the **properties** that **relate** to **temperature**. A relatively **large amount** of **energy** is required to **break** the **bonds** between the **molecules** of water to **change state** from **liquid** to **gas** (high latent heat) or to **increase** the average **temperature** of the water (high specific heat).
- **Evaporation** of water has a **cooling effect**: **Bodies** of **water** have **less extreme temperature ranges** than **land**; and water is **liquid** over a **large temperature range**. These phenomena enable organisms to survive on Earth.
- The **cohesive nature** of the water molecules explains **surface tension**. Understanding this allowed techniques such as **chromatography** to be **developed** and the use of **surfactants** in the **medical**, **detergent** and **food industries**.
- Ice **floats** because of the **regular crystal structure adopted upon freezing**. This **protects** the **life under** the **ice** in the lake **from freezing** and **alters** the **density** of ocean waters.
- Water is the **universal solvent** because it is **liquid** from **0 degrees celsius** to **100 degrees Celsius**. It can **readily dissolve polar substances**, such as **salts** and **polar molecules**. **Salt levels change** the **temperature** at which **water freezes**, allowing some cells to survive extreme temperatures. **Salinity affects** the **density** of water, which **affects** the **convection currents** of the ocean.
- Sometimes, there are **detrimental effects** if the **concentration** of **solutes** is **too low** or **too high**. This knowledge is used in medical diagnosis and in determining water quality. Techniques such as chromatography can determine the amount of solute present.
- Understanding water chemistry and quality enables the **environmental**, **social** and **economic impact** of human activity to be **developed** and **evaluated**, such as how **higher carbon dioxide levels affect** the **acidification** of **ocean ecosystems**, which in turn **affect industries** such as fishing and ecotourism.

CHAPTER GLOSSARY

- **Chromatography** - techniques used to separate components of aqueous, liquid or gaseous mixtures
- **Cryoprotectant** - a chemical that is used to stop biological tissues from freezing
- **El Niño** - a warm ocean current that develops every few years along the coat of Ecuador and Peru
- **Electrolyte** - a charged solute that allows the solution to conduct electricity
- **Enzyme** - a protein molecule that catalyses a specific type of reaction by lowering the energy of activation
- **Eutrophication** - the process in which an additional amount of nutrients leads to excessive growth of plants including microscopic plant like phytoplankton
- **Hard water** - water that contains high level of calcium and magnesium, which interferes with the action of soaps
- **Hydrophilic** - 'water-loving', a particle with polar regions that bond to water
- **Hydrophobic** - 'water-hating', a particle with a mostly non-polar regions that do not bond with water
- **Hypertonic** - concentration of solute is higher than another solution
- **Hypotonic** - concentration of solute is lower than another solution
- **Isotonic** - concentration of solute is the same in solutions
- **Ocean acidification** - lowering of pH of the ocean due to the reaction of carbon dioxide with water molecules
- **Phytoplankton** - microscopic plant like organisms found at the surface of oceans, seas and lakes
- **Solute** - the substance that is dissolved or the smaller component of a solution
- **Solution** - a homogeneous mixture that is formed when a solute dissolves in a solvent
- **Solvent** - the substance in which the solute dissolves or the greater part of a solution
- **Supersaturated solution** - an unstable solution that has more solute than possible at that temperature; it can be formed from dissolving solute into the solution at a higher temperature and then allowing it to cool. The extra solute is still in the solution but can readily be crystallised
- **Surfactant** - a chemical that lowers the surface tension of a liquid
- **Surface tension** - the force that arises from the attraction of the surface molecules to the bulk of the material
- **Suspension** - a cloudy, heterogeneous mixture containing solid particles that will eventually settle out
- **Turbidity** - cloudiness of water due to suspended microscopic particles. High turbidity reduces how far light penetrates into water
- **Viscosity** - the ability of a fluid to resist flow; honey has high viscosity, water has low viscosity
- **Water of crystallisation** - the water molecules that are bonded inside crystals; there is an exact ratio between the water molecules and either the salt or the polar molecule because of the number of ion-dipole or hydrogen bond present between the two

Context 4: Making reactions work for us

CHAPTER SUMMARY

- **Collision theory** allows us to **explain** the **requirements** of a reaction and **understand factors affecting** the **rate** of reaction. We are able to **alter** the rate of reactions by **changing** the **concentration** or **pressure** of **reactants**, **temperature**, **surface area** or **presence** of **catalysts**.
- **Organic catalysts** are known as **enzymes**. They are usually made of **proteins** and are **specific for** a **certain reaction**. Enzymes are affected by **concentration**, **coenzymes**, **temperature** and **pH**.
- **Cellular respiration** is a **chemical reaction** that occurs in the **mitochondria** of cells to **produce energy**. The **rate** of cellular respiration is **dependent** on the **concentration** of **oxygen** and **glucose**.
- **Digestion** provides the body with the **required nutrients** for **survival**. **Chewing** food helps **break** the **food up** into **smaller pieces**, thereby **increasing** the **surface area** available for chemical reactions. This **increases** the **rate** of **digestion**
- The **normal human body temperature** is approximately **37** degrees Celsius. If the **temperature falls too low**, then the **rate** of the **reactions** in the body **decreases** to a **dangerous level**.
- **Fires** are an example of a **chemical reaction**. The **rate** of **reaction** for a fire can be **manipulated** by chopping the wood into **smaller pieces** or **controlling** the **amount** of **oxygen** available.
- **Food spoilage** is the **breakdown** of the **food**, causing it to **change** its **taste**, **texture** or **smell**. Food spoilage occurs when **micro-organisms** or **enzymes** cause a **chemical reaction** that **degrades** the **food**. **Food preservation techniques** utilises different methods of **killing micro-organisms**, **slowing** the **growth** of **micro-organisms** or **slowing** the **chemical reaction**.
- **Batteries** provide **electrical energy** through a **chemical reaction**. When the **concentration** of **reactants** is **low**, the **rate** of reaction is **not fast enough** to produce **efficient** energy and the battery is '**flat**'.
- The **Haber process** is an **industrial** process that **produces ammonia** from **nitrogen** and **hydrogen** gases. The Haber process uses **various techniques** to **increase** the **rate** of the **reaction** to produce **ammonia**, including **increasing** the **temperature**, **increasing** the **pressure** and using a **catalyst**. However, **other factors must** also **be considered** in the Haber process such as **cost**, **safety** and **yield**.

CHAPTER GLOSSARY

- **Active site** - the section of an enzyme where the substrate(s) binds and undergoes a chemical reaction
- **Amino acid** - a small organic molecule that combines to form proteins
- **Biochemistry** - the study of chemicals and their reactions in living organisms
- **Carbohydrate** - an organic molecule made up of one to many molecules of simple sugars
- **Cellular respiration** - reactions that occur in cells to convert the energy in nutrients into energy that can be used; many organisms rely on glucose and oxygen to react to produce carbon dioxide, water and energy
- **Co-enzyme** - a non-protein chemical that binds to an enzyme and is necessary for the function of the enzyme
- **Collision theory** - a theory that explains the rate of reaction at a molecular level; it states that, for a reaction, the particles must collide with sufficient energy and the correct orientation
- **Combustion** - a reaction with oxygen to form the oxides of each of the elements present; with adequate oxygen, combustion of a hydrocarbon will produce carbon dioxide and water
- **Denature** - altering the chemical structure so that the original properties are lost
- **Enzyme** - a protein molecule that catalyses a specific type of reaction by lowering the energy of activation
- **Fat** - an organic molecule that is insoluble in water; many are made up of fatty acids joined to glycerol
- **Food preservation** - methods of slowing the degradation or spoiling of food
- **Food spoilage** - negative changes in food causing changes in taste, smell and feel
- **Haber process** - an industrial process of ammonia production from nitrogen and hydrogen gases
- **Homeostasis** - processes that maintain a stable internal environment of an organism within limits
- **Hypothermia** - the condition of a reduced body temperature (below 35 degrees Celsius) lower than needed for normal metabolism
- **Kinetic energy** - the energy of movement
- **Micro-organism** - a very small organism that can be seen only with the use of a microscope such as a bacterium, virus or protozoan
- **Protein** - a large organic molecule made up of many amino acids joined together
- **Proteolytic enzyme** - an enzyme that breaks proteins into smaller lengths
- **Rate** - how much one quantity changes with respect to another quantity
- **Substrate** - the chemical that fits into the active site of an enzyme
- **Yield** - the amount of product produced during a reaction

Chapter 1: Atoms and elements

1.1 THE ATOM

Atomic particles

- contains three **subatomic particles** - **proton**, **neutron** and **electron**
- proton symbol **p**, charge **+1**, relative mass **1**
- neutron symbol **n**, charge **0**, relative mass **1**
- electron symbol **e**, charge **-1**, relative mass **1/1800** (approx)
- atom's **nucleus** is a very **small** region of space, **contains** all the **protons** and **neutrons**
- nucleus **contains most** of the atom's **mass**, but **occupies** only a **small volume** of the atom
- **electrons surround nucleus**, are very **small**, move extremely **fast** and are **spread out** over a relatively large distance
- creates an **electron cloud** around nucleus, **contributes** almost **no mass** to the atom despite **covering** a **large** space
- **current model** of the atom initially theorised by **Ernest Rutherford** in the early 1900s after an experiment in which he fired **alpha particles** (particles containing **2 protons** and **2 neutrons**) at a thin sheet of fold foil
- **earlier models** suggested that all the particles would be evenly **spread throughout** the **atom**; expected that the **alpha particles** would **pass through** the gold foil with **little** or **no deflection**
- Rutherford found that a **small number** of **alpha particles experienced** a **significant deflection** as though they had **struck something large**
- this didn't support his hypothesis and led to him **theorising** that **most** of the **mass** of the atom was in a **structure in** the **centre** (**nucleus** containing protons and neutrons)

Atomic representation

- **number** of **protons** in the nucleus **defines** the type of **atom**
- a **substance** made of only a **single type** of **atom** is called an **element**
- only **92** if the **elements** identified in the periodic table **occur naturally** on **earth**
- elements with **atomic number** of **93 or higher** have been **synthesised**
- **synthetic elements** exist for only a short period of time after formation - **decay quickly**

- **composition** of **elements** can be represented by $^{A}_{Z}X$
- A = **mass number** (total number of **protons + neutrons**)
- represents **average mass** off all forms of the element that exists
- Z = **atomic number** (represents **number of protons**), number that **defines** an **atom**
- in an atom which is **uncharged**, **number** of **protons** and **electrons** are **equal**, so **atomic number** will also give **number of electrons** in an atom
- **atomic number** is **smaller number**
- X = **symbol of element**, depends of value of Z

What hold an atom together?

- in an atom, **nucleus** has an **overall positive charge**
- **electrons** around nucleus are **negatively charged**
- **attraction between positive nucleus** and **negative electrons** keep atom together - called **electrostatic attraction**
- an atom can be modelled as a **nucleus surrounded** by **electrons**, **held together** by **electrostatic forces** of **attraction** between nucleus and electrons

How a nucleus stays together

- nucleus of an atom is very stable despite being composed only of positive protons and neutral neutrons
- positively charged particles should be **repelling** each other and cause nucleus to break apart but in nucleus there are forces that keep nucleus together
- **electrostatic repulsion** is a **force** that occurs **between particles** with **same charge**
- repulsive forces act between protons on nucleus
- **strong nuclear force** occurs **between all particles** in **nucleus regardless of charge**
- this force is **attractive**, so there is **attraction** between neutrons and neutrons, protons and neutrons and even protons and protons
- force is also **short range** - only works between particles very **close together**
- in a **stable nucleus**, **electrostatic repulse forces** and **short**-**range attractive nuclear forces** are **balanced**
- if forces are **unbalanced**, then **nucleus** will be **unstable** and **decay** over time

WORKED EXAMPLE 1.1

a. Determine the number of protons, neutrons and electrons of:

i. $^{35}_{17}Cl$
Protons - 17, Neutrons - 18, Electrons - 17

ii. $^{48}_{22}Ti$
Protons - 22, Neutrons - 26, Electrons - 22

iii. $^{27}_{13}Al$
Protons - 13, Neutrons - 14, Electrons - 13

iv. $^{137}_{56}Ba$
Protons - 56, Neutrons - 81, Electrons - 56

b. Use correct atomic representation to write the element:

i. Zinc, which has 30 protons and 35 neutrons
$^{65}_{30}Zn$

ii. Phosphorus, which has 15 protons and 16 neutrons
$^{31}_{15}P$

iii. Copper, which has 29 electrons and a mass number of 64
$^{64}_{29}Cu$

iv. Lead, which has a mass number of 207 and 82 protons
$^{207}_{82}Pb$

Element	Atomic #	Mass #	# of protons	# of neutrons	# of electrons
Hydrogen	1	1	1	0	1
Magnesium	12	24	12	12	12
Boron	5	11	5	6	5
Chlorine	17	35	17	18	17
Nickel	28	59	28	31	28

QUESTION SET 1.1

Remembering

1. **Name the three particles in an atom and state the charge of each particle**

Protons - positive charge, Neutrons - no charge, Electrons - negative charge

2. **Describe where each of the three particles is found in the atom**

Protons - in the nucleus, Neutrons - in the nucleus, Electrons - surrounding the nucleus in an electron cloud

Understanding

3. **Explain the balance of forces that exists in a nucleus that makes it stable**

In a stable nucleus, electrostatic repulse forces (force that occurs between particles with the same charge) and short-range attractive nuclear forces (attractive force between all particles in the nucleus) are equal

4. **Name the following elements and calculate the number of protons, neutrons and electrons**
   a. $^{19}_{9}F$
      Fluorine, Protons - 9, Neutrons - 10, Electrons - 9

   b. $^{80}_{35}Br$
      Bromine, Protons - 35, Neutrons - 45, Electrons - 35

5. **Use a periodic table to help you represent the following as $^{a}_{z}X$**
   a. An atom of aluminium with a mass of 27
      $^{27}_{13}Al$

   b. An atom with 4 protons and a mass of 9
      $^{9}_{4}Be$

6. **Copy and complete the following table. You will need to extract information from the periodic table for some elements**

Analysing

7. **Element 113 does not occur naturally. It was synthesised in 2012 by Japanese researchers. It was unstable so it decayed in less than a second. Propose the reason for the rapid decay of this element.**

The forces inside the nucleus were unbalanced causing the nucleus to undergo radioactive decay, emit particles and decay very quickly to try and become balanced. There was so many protons and neutrons packed into the nucleus which also caused it to be very unstable.

1.2 ISOTOPES

- isotopes are **different forms** of **same element**
- they are the **same element** because **number of protons** is the **same**
- however, they have **different numbers** of **neutrons**, which makes them isotopes of each other
- isotopes of different elements can be **naturally occurring** or **synthesised** for a specific purpose
- they show some **similarities** and some **differences** in their **properties**
- their **relative abundance** on earth is **different**
- **number of protons defines** what an element is
- carbon has a number of isotopes all containing six protons
- carbon-12 has six neutrons while carbon-14 has eight neutrons
- **different elements** have **different numbers** of **naturally occurring** isotopes and some, such as fluorine, only have one
- isotopes are **atoms** of an element with **same number** of **protons** but **different number** of **neutrons**
- **isotopes** of **same element** will have very **similar chemical properties**
- **chemical properties** related to **how an element participates** in **chemical reactions**
- when an **atom reacts** in a chemical reaction, its **behaviour** is **due to arrangement** and **number** of **electrons**
- isotopes have **same number** and **arrangement** of **electrons** so their **chemical properties** are **similar**
- **isotopes** of **same element** can have **different physical properties**
- these properties are **features**, such as **colour**, **density** and **mass**, that you can **observe** or **measure**
- properties can **vary** because isotopes have **slightly different masses** due to **different number** of **neutrons**
- e.g. masses of identical amounts of helium-3 atoms and helium-4 atoms will be different

<u>Stable and unstable isotopes</u>

- some isotopes are **stable** because **attractive** and **repulsive forces** in **nucleus** are **balanced**
- other isotopes have **unstable nuclei** in which **forces** are **not balanced**
- in some nuclei, repulsive forces are stronger than attractive forces
- in other nuclei, attractive forces are stronger than repulsive forces
- in both of the cases where **forces** are **not balances**, an **unstable nucleus forms** and **nucleus** will **undergo radioactive decay** to **become usable**
- during radioactive decay, **high**-**energy particles** or **radiation** is **emitted**, which can be used for such purposes as **radioactive dating** and **medical diagnosis** and **treatments**
- isotopes of an element have **similar chemical properties** but **different physical properties**, including **variation** in **nuclear stability**

1.3 RELATIVE ATOMIC MASS

- an atom is **extremely small**, so it is **difficult** to **measure mass** of one atom
- instead, **relative atomic mass** is used **A_r**, which **compares mass** of an atom to mass of another atom
- **atoms** have a **mass** - shown in periodic table; however it **isn't an actual mass**, but a **comparison** that scientists have developed
- scientists arbitrarily picked **carbon-12** as **standard** for **comparison** to **calculate relative atomic mass**
- hydrogen and oxygen considered and used for a time, carbon was selected for **ease of use** in experiments and because it is a **very common element** on earth
- **mass** of a **carbon atom** is considered to be exactly **12** and all others are **compared** to this
- magnesium has twice the mass of carbon so has a mass of 2 x 12 = 24
- hydrogen is one-twelfth the mass of carbon so has a mass of 1/12 x 12 = 1
- **isotopes** of **same element** have **different atomic masses**, also have **different abundances** on earth - they are found in **different amounts**
- e.g two of carbon's isotopes are carbon-12 and carbon-13, on earth, 98.9% of all carbon is carbon-12 and only 1.1% is carbon-13, other isotopes such as carbon-14 are present in such low levels that they're not considered here
- **mass** and **abundance** of **naturally occurring isotopes** of an element are used to calculate **mass numbers** shown in periodic table
- e.g for the two isotopes of carbon, equation is -
- **mass number** = (**abundance percentage** x **atomic mass**) + (abundance percentage x atomic mass) **divided by 100**
- **(98.9 x 12) + (1.1 x 13) / 100 = 12.01**
- relative atomic mass numbers **not whole numbers**
- mass number of carbon is calculated by **factoring in abundance** and **mass** of each isotope
- atomic mass of carbon does not really include 0.01 of a proton or a neutron, is simply an **average** of the isotope masses that exist on earth
- relative atomic mass of an element is **ratio** of **weighted average mass per atom** of naturally occurring form - **reflects isotopic composition** of element

WORKED EXAMPLE 1.2

a. Lithium has two isotopes, lithium-6 with an abundance of 7.59% and lithium-7 with an abundance of 92.41%. Calculate the relative atomic mass of lithium

mass number = (abundance percentage x atomic mass) + (abundance percentage x atomic mass) divided by 100

mass number = (7.59 x 6) + (92.41 x 7) / 100

Lithium relative atomic mass = 6.92

b. Magnesium has three isotopes, magnesium-24 with an abundance of 78.99%, magnesium-25 at 10.00% and magnesium-26 at 11.01%. Calculate the relative atomic mass of magnesium

mass number = (abundance percentage x atomic mass) + (abundance percentage x atomic mass) + (abundance percentage x atomic mass) divided by 100

mass number = (78.99 x 24) + (10 x 25) + (11.01 x 26) / 100

Magnesium relative atomic mass = 24.32

QUESTION SET 1.2

Remembering

1. Define 'isotope'

An isotope is an atom of an element with the same number of protons but a different number of neutrons

2. Explain 'relative atomic mass'

Relative atomic mass is a comparison between the mass of an atom to the mass of another atom. It is used because an atom is extremely small so it is difficult to measure the mass of one atom.

Understanding

3. Explain the difference in structure between the isotopes nitrogen-14 and nitrogen-13

Nitrogen-14 has an atomic mass of 14, with 7 neutrons where as Nitrogen-13 has an atomic mass of 13, with 6 neutrons

4. Explain how the relative atomic mass shown in the periodic table is calculated

The mass of a carbon atoms considered to be exactly 12 so all other element's relative atomic mass is compared to this based on it's mass. For example, one titanium atom has the same mass as four carbon atoms, therefore the relative atomic mass of titanium is 4 x 12 = 48

5. Explain why isotopes of the same element have the same chemical properties

Isotopes of the same element have the same chemical properties (how an element participates in a chemical reaction) because an atoms behaviour when it reacts in a chemical reaction is due to its arrangement and number of electrons, and isotopes have the same arrangement and number of electrons

6. Explain why some isotopes are stable and some are unstable

Some isotopes are stable because the attractive and repulsive forces in the nucleus are balanced. Other isotopes are unstable because the forces in the nucleus are unbalanced. When an isotope is unstable, it undergoes radioactive decay to become stable.

7. Use your understanding of isotopes to explain how they might be useful

During radioactive decay of unstable isotopes, high-energy particles or radiation is emitted which can be used for radioactive dating and medical diagnosis and treatments

Applying

8. An element has a mass three times that of carbon. Calculate its relative atomic mass

3 x 12 = 36. Relative atomic mass of 36amu

9. Copper has two isotopes: copper-63 with an abundance of 69.17% and copper-65 with an abundance of 30.83%. Calculate the relative atomic mass of copper

mass number = (69.17 x 63) + (30.83 x 65) / 100

Copper relative atomic mass = 63.62amu

10. Vanadium (V) has two naturally occurring isotopes, vanadium-50 and vanadium-51/ Given that the mass number for vanadium in the periodic table is 50.94, predict which isotope is more abundant and explain your reasoning

Vanadium-51 is more abundant as it is closer to the mass number on the periodic table meaning that it must of had more weight in the weighted average/ relative atomic mass calculation

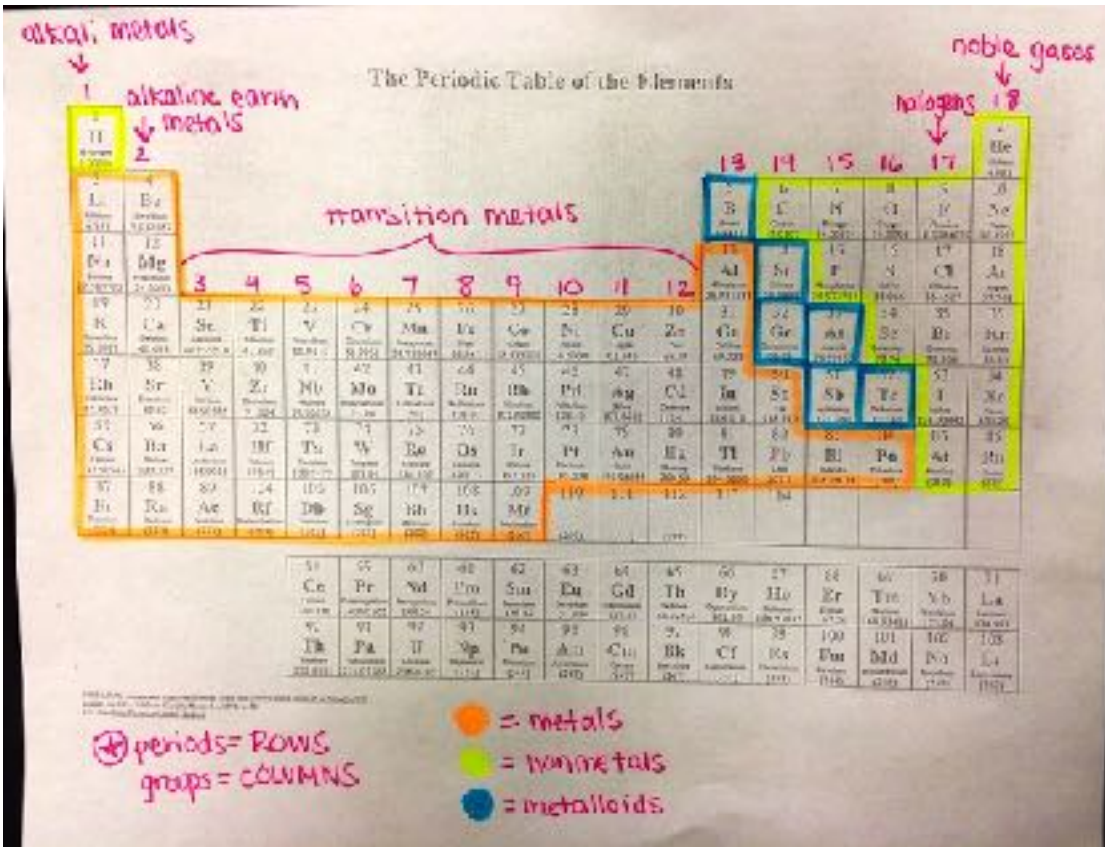
1.4 PERIODIC TABLE

<u>History of the periodic table</u>

- first periodic table developed by **Dmitri Mendeleev** in **1869**
- **first table** to be **arranged** in **current structure**
- elements were arranged by **increasing atomic weight, trends** in **columns**, **rows** and **across whole table** could be seen
- Mendeleev left **gaps** for **elements not discovered** at the time, was able to **predict** their **mass** and **properties** from **trends** shown

<u>Arrangement of the periodic table</u>

- arranged in series of **horizontal rows** - **periods** and **vertical columns** - **groups**
- elements in **order of** their **atomic number** from left to right in each row
- **similar properties** found in **vertical groups** numbered 1-18
- some groups are named e.g. transition metals, group 1 - alkali metals
- each element in **same group** show **similar chemical properties**
- e.g when reacted with water, each group 1 element will form a metal hydroxide and hydrogen gas. this reaction with water becomes more violent as you go down group
- **trend** in groups e.g. **reactivity** of **elements** in group 1 **increases down group**
- periods on the periodic table are given numbers 1-7
- elements in a **period** display very **different properties** and **chemical reactivity**
- helps determine whether an element is a **metal**, **non-metal** or **metalloid**
- **metalloid** - element that has **properties** of **both metals** and **non-metals**



QUESTION SET 1.3

Remembering

1. **Describe how Mendeleev arranged the elements in the periodic table**

Mendeleev arranged the elements in the periodic table increasing in atomic weight from left to right in such a way that trends in columns, rows and across the whole table could be seen. He also left gaps for undiscovered elements and was able to predict their masses and properties from the trends in his periodic table

2. **Identify where you would find the metals, non-metals and metalloids in the periodic table**

Metals appear on the left-hand side of the table, non-metals are on the right-hand side and metalloids are in a diagonal strip between them - B, Si, Ge, As, Sb, Te

3. **Explain the difference between a group and a period**

Periods are the horizontal rows and columns are the vertical rows. Elements in each group all have similar properties whereas elements in each period all display very different properties

4. **Identify the groups that have been given common names, such as the noble gases. Make a table showing the group number and the common names of these groups**

Group number	Common name
1	Alkali metals
2	Alkaline earth metals
17	Halogens
18	Nobel gases
3-12	Transitional metals

Understanding

5. **Describe what all the elements in group 2 have in common**

All elements in group 2 have two electrons in their outer shell and all have similar chemical properties

6. **Describe what al the elements in group 15 have in common**

All elements in group 15 have five electrons in their outer shell and all have similar chemical properties

Analysing

7. **Suggest a reason why all the elements in the same group might undergo the same chemical reactions**

All the elements in the same group have the same number of electrons in the outer shell and therefore have very similar chemical properties

8. **If beryllium reacts with fluorine gas to make beryllium fluoride, predict what would happen if you placed some magnesium metal in a gas jar containing chlorine gas. Explain your answer**

It would make magnesium chloride as beryllium and magnesium are both in group 2 and fluorine and chlorine are both in group 17

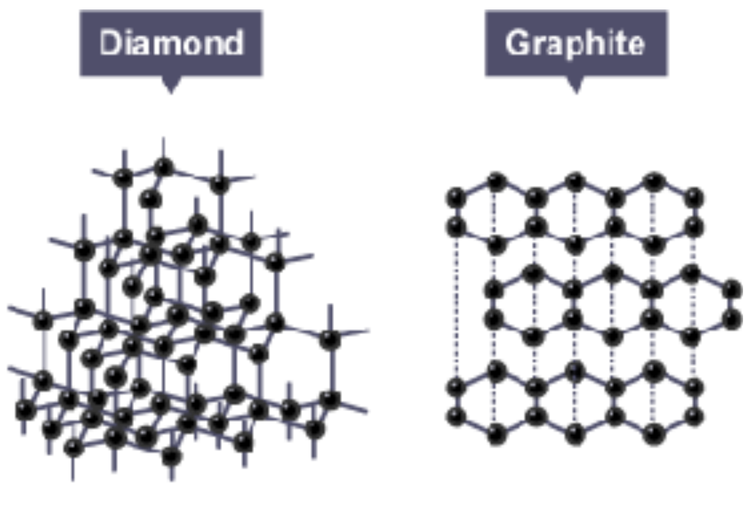
1.5 ELEMENTAL CARBON

- **carbon** as an element exists in several different forms called **allotropes**
- allotrope - **different physical form** of the **same element**
- **atoms** in each allotrope are **arranged differently**, giving it **different properties**
- best-known **allotropes** of carbon are **diamond**, **graphite** and **coal**
- each of these are **composed entirely of carbon** but are **very different** from one another
- **diamond** - **hardest** known **naturally occurring** material
- **graphite** is an **extremely soft** substance, **leaves layers** of itself on paper which is why it is **used in pencils**
- **diamond** is a **transparent** substance; **graphite** and **charcoal** are **opaque** and **dark** coloured
- **diamond** is a **poor electrical conductor**, while **graphite** is an **excellent conductor** of **heat** and **electricity**
- **properties** of each substance **depends on** its **bonding**, and determines how it is used in society
- **carbon** - has a lot of applications in **nanotechnology**, particularly construction of **carbon nanotubes** - exceptionally **good conductivity**, used in **material constructions**, **electronics** and **optics**


Diamond


Graphite


Charcoal



1.6 ELECTRON ARRANGEMENT

- **arrangement** of **electrons** around atom's nucleus is used to predict **chemical reactivity**
- all chemical reactions involve **sharing** or **transfer** of electrons between atoms involved

Energy levels

- electrons are found in specific **energy levels** (or **energy shells**) around **nucleus** of the atom
- electrons in the **same energy level** have the **same amount** of **energy**
- **higher energy level** an electron occupies, the **more energy** it has
- every electron in an atom has to be in an energy level, cannot exist between levels
- can **move between energy levels** when atoms **absorb** and **release energy**
- **each** energy **level** in an atom can only **hold** a **certain number** of electrons
- **first** level holds maximum of **two** electrons, **second** can hold up to **eight** electrons
- formula **$2n^r$** - determine **maximum number** of **electrons** an energy level can hold, where **n** is the **energy level number**
- e.g. energy level 3 can hold $2 \times 3^2 = 18$ electrons
- **energy levels** correspond to the **horizontal periods** in the periodic table

Electron configuration

- electrons arranged in **specific ways unique** to each atom - **electron configuration**
- **electrons** around a nucleus **fill up in order** and **occupy lowest** energy **levels first**
- configurations written to show **how many electrons** are in **each level**, and **order** of levels

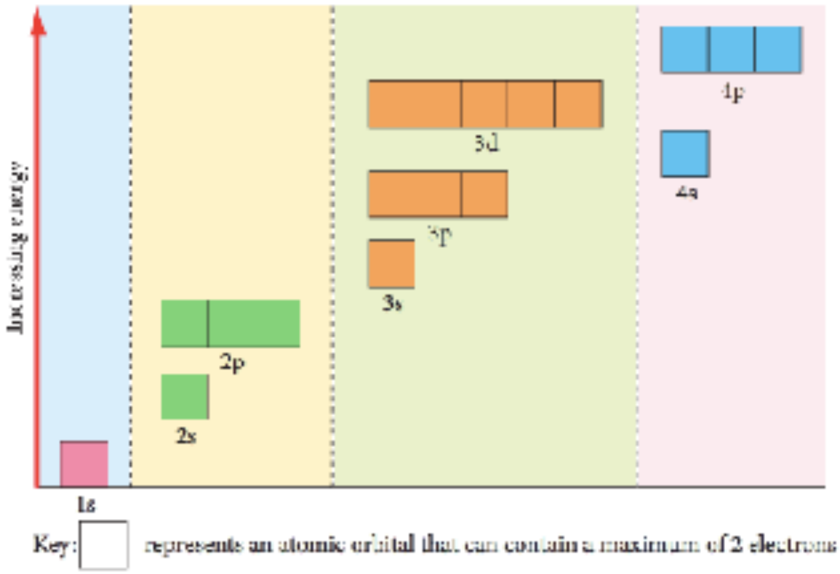
Subshells

- **previous method** of writing electronic configurations **focuses only on** what happens to **electrons inside** a **whole energy level**
- however, **each major energy level contains one** or **more subshells**, designated **s, p, d** and **f**
- each **subshell contains regions** of **physical space** called **atomic orbitals**, inside which **electrons move**
- each **atomic orbital cannot contain more than two electrons** and if it does **contain two** electrons, they **spin in opposite directions**

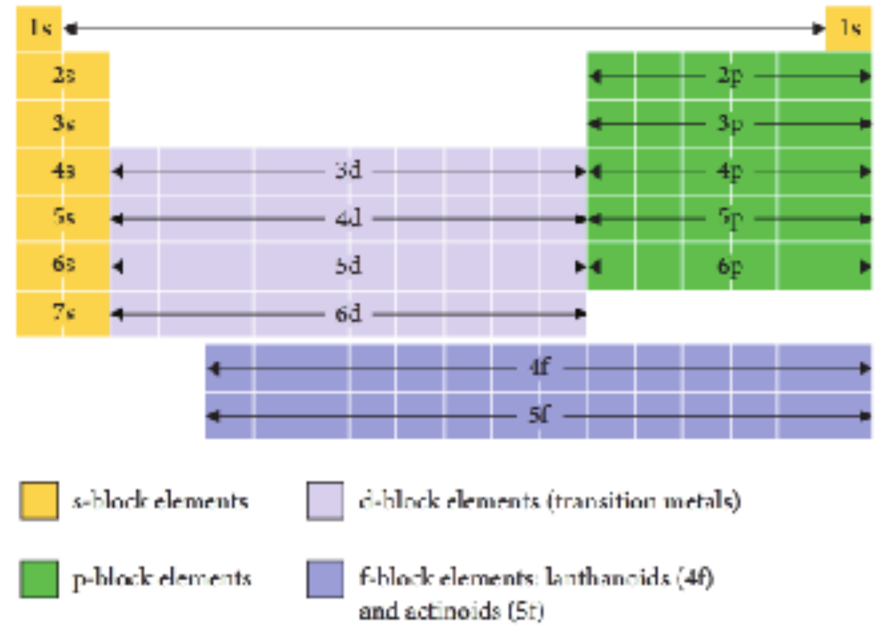
Subshell designation	Number of orbitals	Number of electrons in subshell
s	1	2
p	3	6
d	5	10
f	7	14

- **first energy level** has only **one subshell** - **s subshell**, and is given the designation **1s**
- **second energy level** has **two subshells** - **s and p**, given the designation **2s** and **2p**
- **third energy level** has **three subshells** - **s, p and d**, given the designation **3s, 3p and 3d**
- **fourth energy level** has **four subshells** - **s, p, d and f**, given the designation **4s, 4p, 4d and 4f**

- the **number** in front represents **main energy level, letter** represents a **particular subshell**
- these subshells have **different** energy levels
- in a particular energy level, **s subshell** always has **lowest energy**, followed by the **p subshell**, then **d** and **f** subshells



- subshells can also be seen in the periodic table
- **group 1 and 2** are the **s block**, **groups 13-18** are the **p blocks**, the **transition metals** are the **d block** and the **lanthanoids and actinoids** are the **f block**



- periodic table can be used to predict which subshells have higher or lower energy than others
- subshell with the **lowest energy** is the **1s subshell**
- 1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p
- found by reading across periodic table from left to right

- each **transition metal row** includes a **subshell** that belongs in the **energy level above** the row it is in
- e.g. the **d subshell** in the **fifth row** of the periodic table is the the **d subshell** in the **fourth energy level**, subshell **4d**
- we **fill up** the **subshells** just as we **filled up** the **energy levels** in **electron configuration method**
- **hydrogen** has an electron configuration **$1s^1$**, with the **superscript 1 representing** the **number of electrons** in the **subshell**
- **helium** is **$1s^2$**
- for lithium, the **next electron** needs to go into the **next subshell**
- **lithium** is **$1s^2\ 2s^1$**
- **beryllium** is **$1s^2\ 2s^2$**
- **boron** is **$1s^2\ 2s^2\ 2p^1$**
- **neon** is **$1s^2\ 2s^2\ 2p^6$**
- **sodium** is **$1s^2\ 2s^2\ 2p^6\ 3s^1$**
- **argon** is **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$**
- **calcium** is **$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$** etc

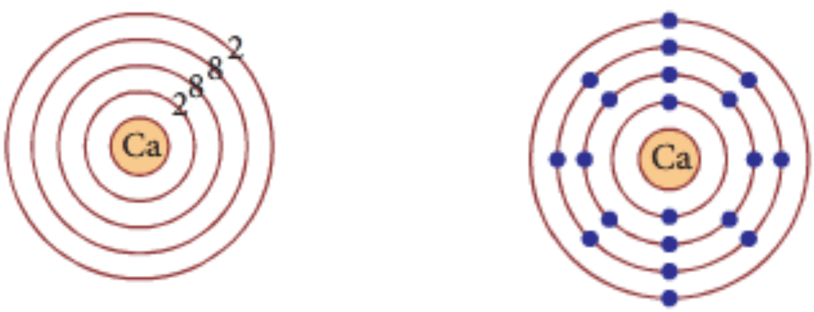
<u>Representing electrons</u>

- the **arrangement** of **electrons** around a **nucleus** can be **represented visually** in a number of different ways
- each of these highlights parts of our understanding of how electrons are arranged around a nucleus

<u>Electron shell diagrams</u>

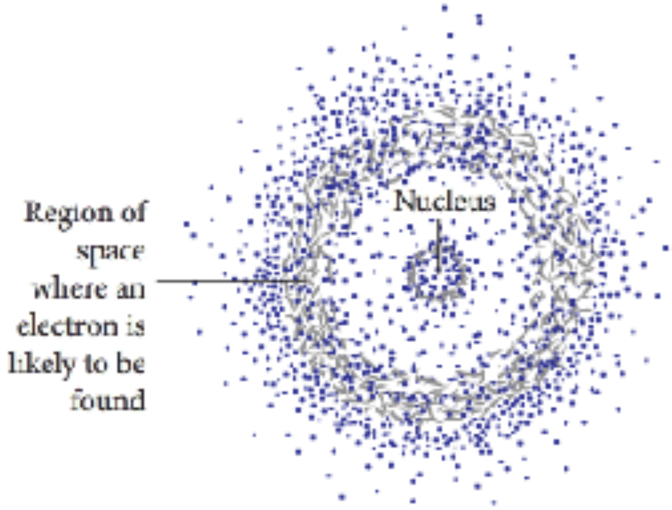
- a simple electron shell diagram shows the **arrangement** of **electrons** in their **energy levels**
- can be represented by showing **each electron individually** or by using the **number of electrons**
- lowest energy shell is closest to nucleus

Figure C1.12 ▼ Two versions of an electron shell diagram for calcium



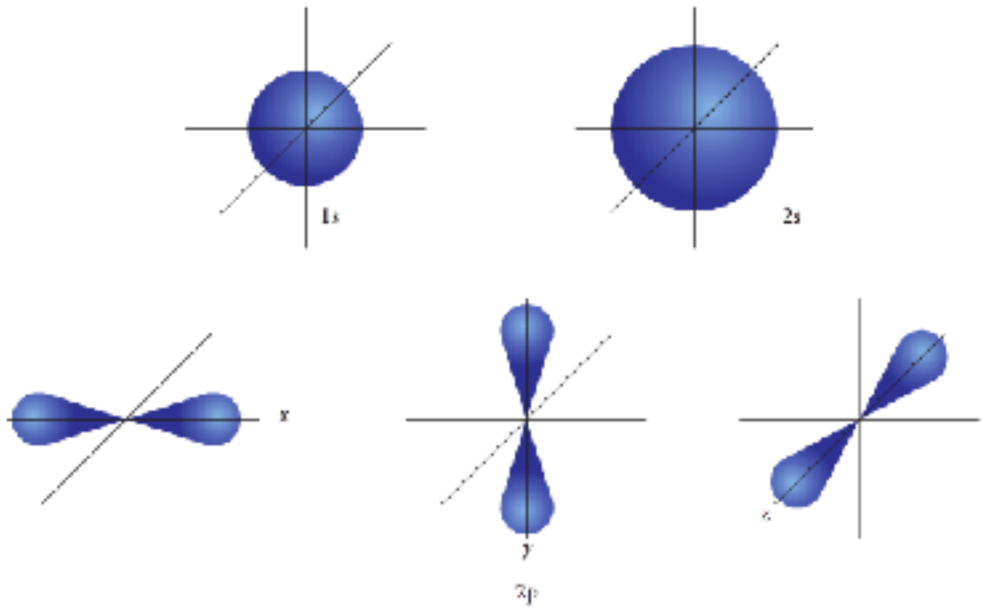
Electron charge cloud diagram

- electrons around a nucleus exist in **regions of space**
- **impossible** to **identify exactly where** an **electron** is **located** in an atom, only **region of space** in which it is **likely to be**
- electron charge cloud diagrams used to show **probability** of **electrons being found** in a **particular place** in the atom
- unlike electron shell diagrams, this type of representation **doesn't show** how **electrons** are **arranged** in **energy levels**, simply the **region of space** around nucleus where an electron is **likely** to be **located**



Atomic orbital diagram

- each of the **four orbitals, s, p, d and f** have a **specific shape** that can be **mapped** to **show** the **physical space** that **electrons occupy**
- the electrons in a particular orbital are found somewhere within that region of space



- electrons exist in **distinct energy levels**, which can be represented by **electron shell diagrams** or **electron charge clouds**

Chemistry ATAR

QUESTION SET 1.4

Remembering

1. State how many electrons are found in the third energy level

18 electrons are found in the third energy level

2. Describe how electrons fill up the energy levels in an atom

Electrons fill up around a nucleus in order and occupy the lowest energy levels first

3. Explain what is shown in an electron cloud diagram

Electron cloud diagrams show the probability of electrons being found in a particular place in the atom

Understanding

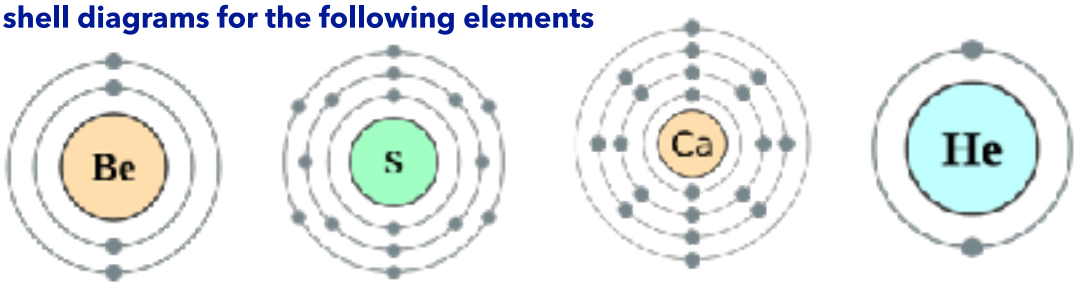
4. Draw electron shell diagrams for the following elements

a. Beryllium

b. Sulfur

c. Calcium

d. Helium



5. Write electron configurations for the following elements

a. Nitrogen
   2, 5 / $1s^2\ 2s^2\ 2p^3$

b. Phosphorus
   2, 8, 5 / $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

c. Hydrogen
   1 / $1s^1$

d. Scandium
   2, 8, 8, 3 / $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1\ 4s^2$

e. Germanium
   2, 8, 18, 4 / $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^2$

6. Identify the elements that have the following electron configurations

a. 2, 8, 2 / $1s^2\ 2s^2\ 2p^3$
   Magnesium

b. 2 / $1s^2$
   Helium

c. 2, 8, 14, 2 / $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$

Iron

Analysing

7. **The following electron configurations are incorrect. Identify each element, explain why the configuration is incorrect and write the correct configuration for that element**
   a. 2, 9
      Sodium - 2, 8, 1 - $1s^2$ $2s^2$ $2p^6$ $3s^1$

   b. 2, 8, 10
      Calcium - 2, 8, 8, 2 - $1s^2$ $2s^2$ $2p^6$ $3s^2$ $3p^6$ $4s^2$

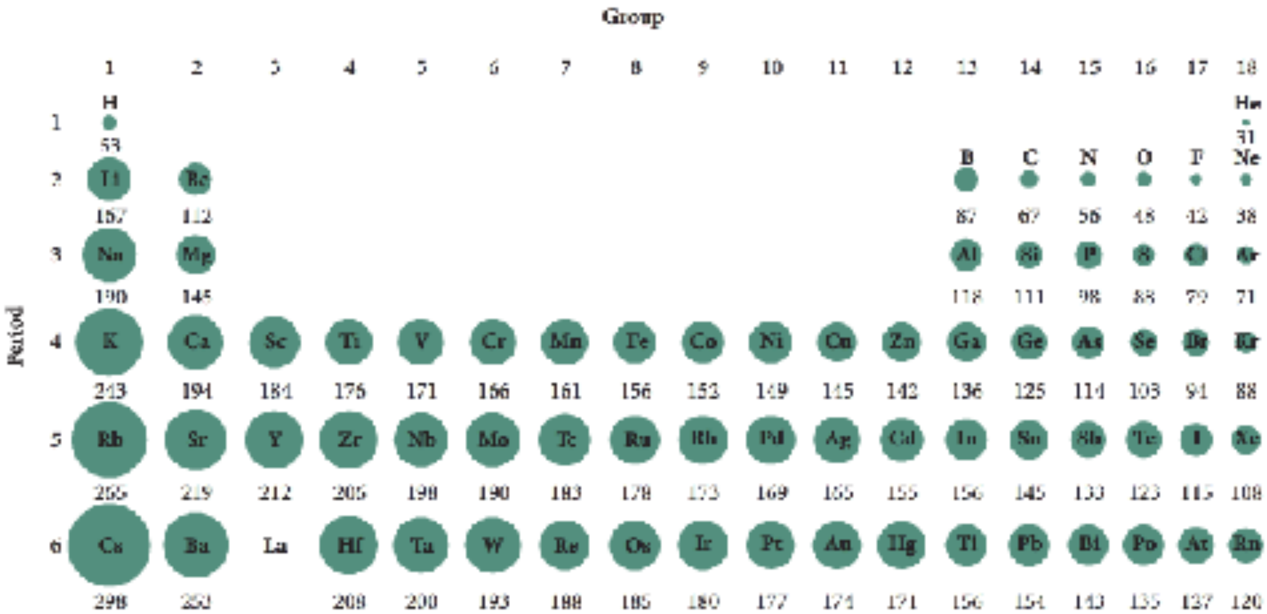
1.7 PERIODIC TABLE TRENDS

Valence shell electrons

- number of **electrons** in the **valence** (**outer**) **shell** of elements in groups 1,2, 13-18 can be determined from periodic table
- number of **valence electrons** = **group number**
- e.g. all elements in group 1 have 1 valence electron
- this doesn't work for the transition metals

Atomic radius

- measured as **distance** from **nucleus** to **boundary of cloud** of **electrons** surrounding it
- atomic radius **decreases** from **left** to **right** across a **period**
- **positive charge** of **nucleus increases across group** - due to **extra protons** in nucleus
- as **nucleus** becomes **more positive**, **electrons** in **outer energy level** are more **strongly attracted** to **positive nucleus** and **move closer together**, **decreasing radius**
- atomic radius **increases down** a **group**
- elements at **bottom of group** have **more energy levels filled** than those at top of group
- more energy levels filled - **distance between nucleus** and **outer energy level increases**, so atomic radius does as well

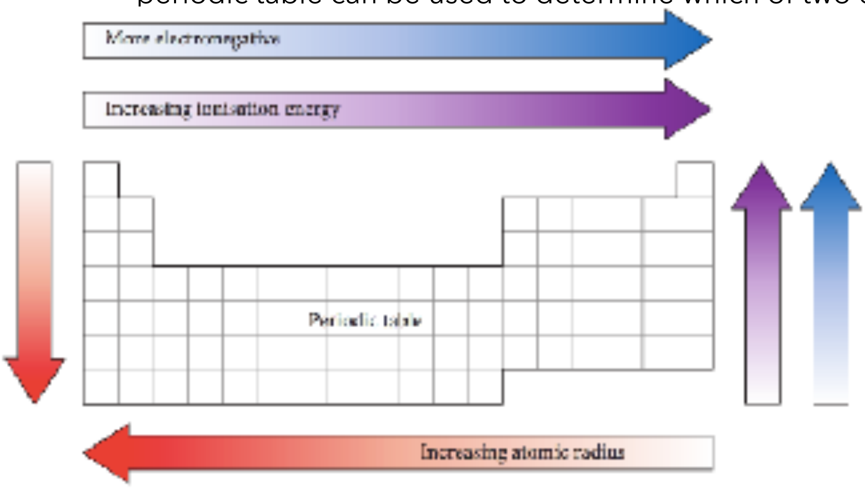


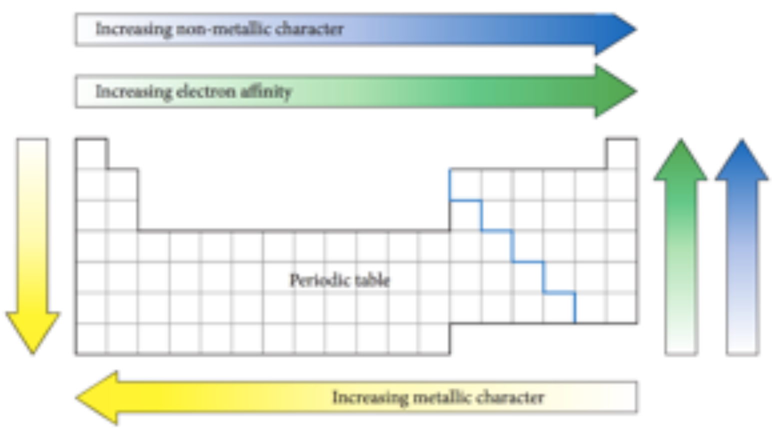
<u>Ionisation energy</u>

- Ionisation energy - **amount of energy needed** to **remove** an **electron** from a **neutral atom** when it is a **gas**
- an atom that has **low ionisation energy** will become an **ion** (a charged atom) **very easily**
- ionisation energy **increases** from **left** to **right** across a **period**
- within a **period**, **electrons** are in **same energy level** - all approximately **same distance from positively charged nucleus**
- **across period**, number of **protons increases**, so **positive charge** of **nucleus** also **increases**
- **attraction** between **positive nucleus** and **negative electrons** become **strong**, making it **harder to remove** an **electron**, so **more energy** is **needed**
- ionisation energy **decreases down** a **group**
- **down** a **group**, **electrons** in their **energy levels** are **getting further away** from **nucleus** and are **less strongly bound** to **positive nucleus**
- so it **takes less energy** to **remove electron** from the atom because there is **weaker attraction** between **positive nucleus** and **negative electrons**

<u>Electronegativity</u>

- electronegativity - ability of an atom to **attract electrons toward itself**
- electronegativity **increases** from **left** to **right** across a **period**
- **nucleus** is becoming **more positive** and so **electrons in** the **atom** become **more closely attracted** to **nucleus** and **atomic radius decreases**
- as atom gets **smaller**, atoms have a **stronger attraction** for **electrons** of nearby atoms
- electronegativity **decreases down** a **group**
- as number of **energy levels increases**, **electrons** are **further away** from **nucleus** so **attraction** between **positive nucleus** and **negative electrons** is **weaker**, **atomic radius increases**, and it is **harder** for an **electron** to be **attracted** to the atom
- periodic table can be used to determine which of two elements is more electronegative





Electron affinity

- electron affinity - ability of **an atom** in **gaseous state** to **accept an electron** and **form** a **negative ion**
- different from electronegativity - involves full edition of an electron, not just ability to attract electrons
- electron affinity **increases across** a **period** from **left** to **right**
- because **atomic radius decreases**, **outer energy levels more strongly attracted** to **positive nucleus**, is **easier to add** an **electron** to these atoms
- electron affinity **decreases down** a **group**
- **harder for atoms** to **add** an **electron**
- **more energy levels** in these elements, **electrons** are **further away from nucleus**
- **attraction** between **positive nucleus** and **negative electrons** is **weaker** - **harder to attract** and **add electrons** to this atom

Metallic character

- elements classed as **metals**, **non-metals** or **metalloids**
- metallic character **decreases across** a **period** from **left** to **right**
- metallic character **increases down** a **group**
- elements on **left** of periodic table are **metals**, elements on **right** of table are **non-metals**
- strip of elements along **diagonal line** consist of **metalloids** - have **characterises** of **both metals** and **non-metals**

QUESTION SET 1.5

Remembering

1. State how many electrons are found in the outer shells of:

a. Beryllium
2

b. Fluorine
7

c. Phosphorus
5

d. Sodium
1

e. Argon
8

2. Define 'metalloid'

An element with characteristics of both metals and non-metals

3. Define 'ionisation energy'

Ionisation energy is the amount of energy needed to remove an electron from a neutral element when it is a gas to form a positive ion

4. Describe the trend in metallic character in the periodic table

Metallic elements are found on the left, non-metallic elements are found on the right table. Metallic character increases from left to right across a period and increases down a group.

Understanding

5. Explain, using electron configurations, how many electrons are found in elements in group 17

The elements in group 17 all have 7 electrons in their outer electron shell plus full electron shells for the rest of the period number they are in

Applying

6. State whether lithium or fluorine would have a bigger atomic radius

Lithium

7. In the following pairs of electrons state which element is more electronegative

a. Nitrogen and oxygen
   Oxygen

b. Magnesium and beryllium
   Beryllium

c. Phosphorus and fluorine
   Fluorine

d. Carbon and silicon
   Carbon

Analysing

8. Explain why atomic radius changes across a period and down a group

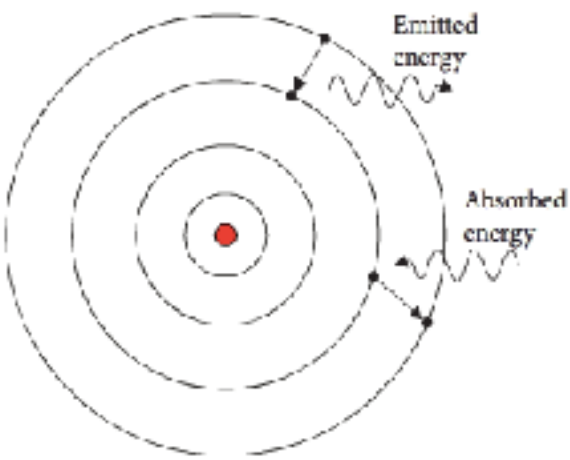
Atomic radius decreases from left to right across a period due to the elements having more protons in the nucleus causing a stronger attraction between the nucleus and electrons, moving the electrons towards the nucleus therefore decreasing the radius size. Atomic radius increases as elements at bottom of group have more energy levels filled than those at top of group

1.8 ELEMENTAL SPECTRA

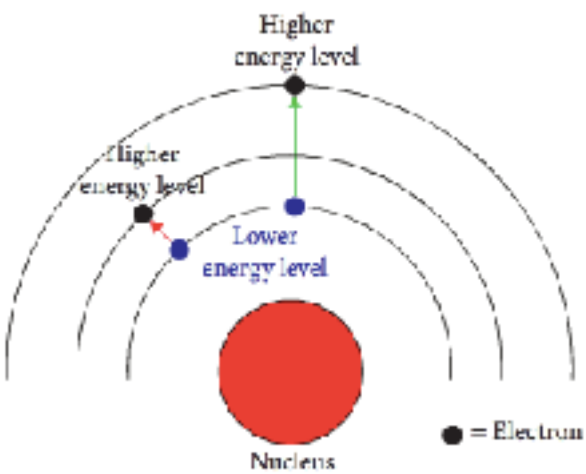
- In an atom, **electrons** are found in a **specific arrangement** around the nucleus
- When all **electrons** are in **lowest possible energy levels**, **atom** is said to be in **ground state**

Movement of electrons

- when an **atom absorbs energy**, such as **heat**, **electrons** in energy levels around nucleus **gain** this **extra energy** and can **move up to** a **higher energy level**
- **energy levels** for **electrons** in an atom occur at **particular levels** for a **particular element**
- electrons **cannot exist between energy levels**
- **amount** of **energy** they **absorb** can only be equal to the **difference between one energy level and another**
- an **electron** may **rise** one level or by **more than one level**
- e.g. **energy levels** in every magnesium atom are **identical**
- when **energy** is **added** to a sample of magnesium, **all electrons** will **move between** the **same**, **set energy levels**
- **amount of energy absorbed** by **any sample** of the element will be the **same**
- as an atom can have **multiple energy levels**, it is possible for an **electron** to **move up one**, **two** or even **more energy levels**
- an atom with **electrons** in **upper energy levels** - in an **excited state**
- electrons in **excited**, **higher energy levels** are **unstable**
- **after very short time**, less than one-millionth of a second, electrons **move down** to their **original energy levels**
- as they do, they **release** the **energy** they **previously absorbed**
- energy is **emitted** as **light**
- energy related to **wavelength** of **light produced**, so this light has a very **specific wavelength**
- because electrons can **move between** a **number** of **different levels**, **different wavelengths** of light are **emitted** from a sample
- as all magnesium atoms have the **same energy levels**, the **light emitted** by all magnesium atoms will have a **consistent set of wavelengths**
- oxygen and **other elements** will have a **different set of energy levels** from magnesium
- energy levels in oxygen are **still discrete** and **electrons** will still **move between levels** but they will **absorb** and **emit light** of **different energies** from electrons of magnesium
- light emitted by oxygen will have **different wavelengths** from the light emitted by magnesium



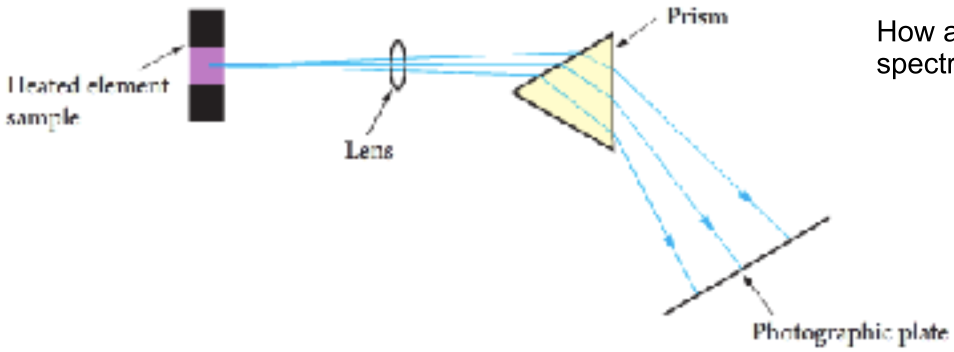
▲ Figure C1.19
Absorption and emission of light by atoms due to electron movement



▲ Figure C1.18
When electrons absorb energy, they can move between energy levels

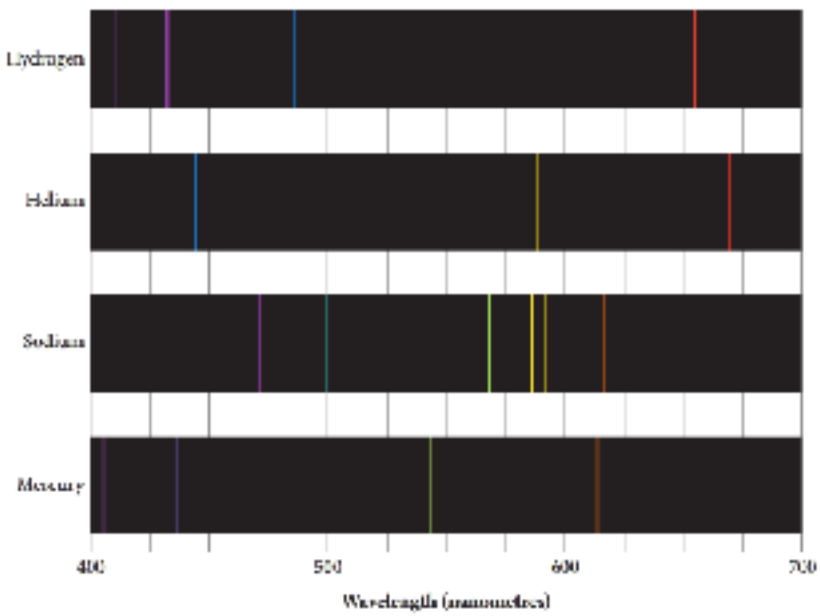
Emission spectroscopy

- the **absorption** and **emission** of **light** by an element can be used to define it
- when a sample of an element is **heated** it will **absorb energy**
- its **electrons** will **move to higher energy levels** and **fall back down** to **ground state**, **emitting light**, which can be **analysed**
- process of **analysing light** is called **spectroscopy**
- **spectroscope** - device used to **take light emitted** from an **element** and **separate** it into its **component wavelengths** to produce a **line emission spectrum**
- **light** is composed of **multiple wavelengths**, which are **dispersed through** a **prism** and **shone onto** a **film** to **produce** a **spectrum**



How a line emission spectrum is formed

- each element has a **unique set of energy levels**, so when **electrons move between them**, it will **involve absorption** and **emission** of **different amounts** of **energy**
- every element will **emit light** of a **different set** of **wavelengths** from every other element



Emission spectrum of some common elements

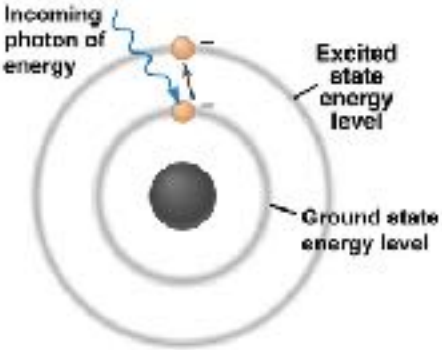
- because **every atom** of the **same element** has the **same set** of **energy levels**, **patterns produced** for an element will always be the **same** - way of **identifying** an **element**
- an **unknown element** is **heated** and **light** it emits is **analysed** and **compared** with known spectra

QUESTION SET 1.6

Remembering

1. **Explain 'ground state' and 'excited state' in reference to electrons in an atom. Use a diagram in your answer**

When an atom is in ground state all of its electrons are in the lowest energy level. When an atom is in excited state its electrons have moved to upper energy levels as the atom has absorbed energy.



2. **Describe what happens to electrons when an atom absorbs energy**

When an atom absorbs energy the electrons gain this energy and move up to higher energy levels for a short time and the atom enters an excited state

3. **Describe how an atom can emit energy**

An atom can emit energy in the form of light

4. **Describe a spectroscope and how it works**

A spectroscope is a device used to take the light emitted from an element and separate it into its component wavelengths to produce a line emission spectrum which can then be used to find out what unknown elements are by comparing it to known elements. The heated element sample emits light which is passed through a lens through a prism which separates the wavelengths and shines it on to a photographic plate.

Understanding

5. **Explain why all atoms of sodium will emit the same set of wavelengths of light when heated**

They emit the same set of wavelengths because all atoms of sodium have the same set of energy levels

6. **Explain why sodium and magnesium have different emission spectra**

They have different emission spectra because they emit different sets of wavelengths as they have different a set of energy levels to each other

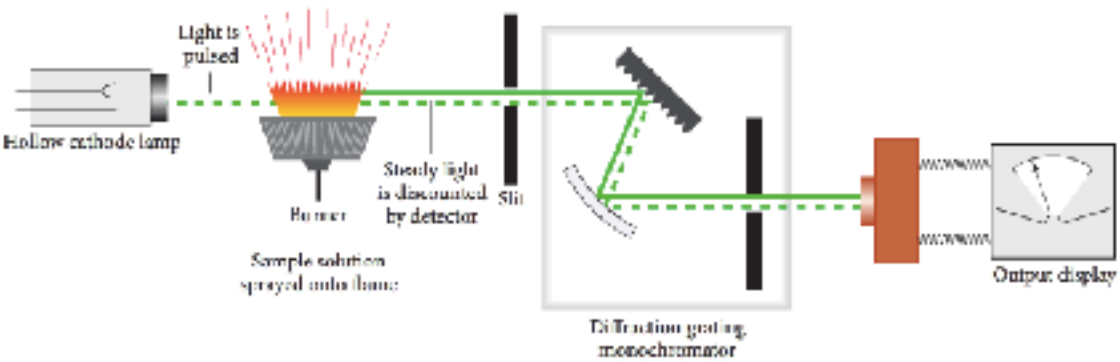
Applying

7. **Identify the unknown element, giving reasons for your answer**

The unknown element is sodium because the unknown element emission spectra matches with the known sample of sodium

1.9 Atomic absorption spectroscopy

- **atomic absorption spectroscopy** is a related technique to emission spectroscopy, can also be used to **perform qualitative analysis**; to find **amount of** an **element present**
- uses the **absorption of light** by **electrons** in the atom to **measure how much** of an **element** is **present** in a sample of substance



The process of atomic absorption spectroscopy using an atomic absorption spectrometer

- first, **element** being **analysed** is **determined**, important because element **in question** is usually **part of** a **sample of material** such as **food**, **paint** or **soil**
- as there are **multiple elements present** in these substances, **shining normal light** through them would be **useless** - **all elements** would **absorb light**, need to **focus on one** element only
- **lamp** for this process is **made of** the **same element** being **tested**
- e.g if zinc is being tested for, then the lamp is made of zinc
- an **electric current** is **passed through** a **gaseous sample** of the **element** so it will **emit light**
- when **lamp** is made of a **single element**, then **light emitted** has **only** the **unique set** of **wavelengths particular to that element**
- **sample** being tested is **vaporised**, **changing substances** it contains **into atoms**
- when **light** from lamp **passes through vaporised sample**, only **element being tested** for will **absorb light** from lamp
- because is has the **same energy level** as the **atoms** that **emitted** the **light** from lamp
- **other elements** in vaporised sample **will not absorb** this **light** because **energy levels** of **all other atoms** are **different** and **their electrons cannot absorb** the **energies** of **light** present
- **light** passes **through sample** and is **focused through** a **slit** before entering **monochromator**
- this **selects one wavelength** of **light** for **analysis by** the **detector**
- detector **measures intensity** of **light**, which is then **displayed as** a **number**
- this number is **measure of** the **amount of light** that **passed through sample** without **being absorbed** - called an **absorbance value**
- **atomic absorbance spectroscopy** relies on **electron transfer** between **atomic energy levels,** can be used to **identify** elements

A qualitative tool

- to **measure amount** of an **element present**, **absorbance** of a **sample** is **compared** to that of **known samples**
- done by constructing **calibration curve**
- first, a **number** of **known concentrations** of the **element** are **prepared** and their **intensities** are **measured** by **atomic absorption spectroscopy**
- then, a **calibration curve** of **concentration against absorbance value** is **plotted**
- **allows concentration** of **another sample** to be **compared** and **determined** once its **absorbance** is **measured**

WORKED EXAMPLE 1.3

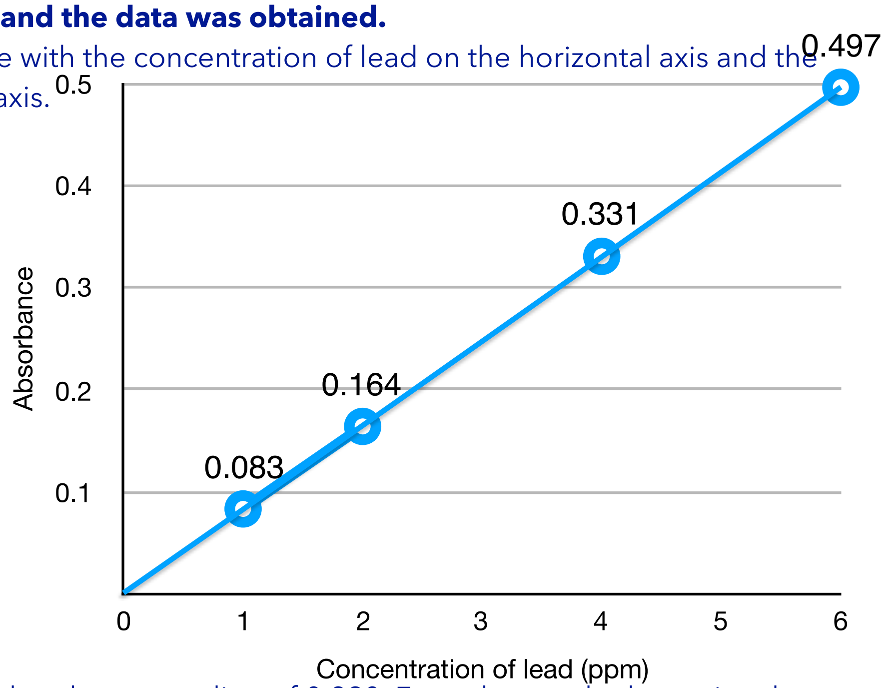
a. Samples of the water from the mine were analysed and the following absorbance values were obtained. For each absorbance reading, use the graph to determine the concentration.

i. 0.75
3.5 ppm

ii. 0.30
1.5ppm

b. A sample of soil was suspected of containing high levels of lead, which is dangerous for people working with that soil. To determine the concentration of lead in the soil, a lead lamp was used in the spectroscope to analyse the soil. Lead samples of known concentration were analysed and the data was obtained.

i. Construct a calibration curve with the concentration of lead on the horizontal axis and the absorbance on the vertical axis.



ii. The sample of soil gave an absorbance reading of 0.290. From the graph, determine the concentration of lead in the soil.
3.6ppm

iii. Safe levels of lead in the soil are less than 3.5ppm. Explain whether this sample of soil would be safe to work with.
It would not be safe as the concentration is higher than 3.5ppm

1.10 MASS SPECTROMETRY

- another **method** of **analysing elements** is mass spectrometry
- unlike emission and absorption spectroscopy, this method is **not** based on light or promotion of electrons to a higher energy level
- it is **based on different masses of atoms** in a sample
- can be used to **determine** what **elements** are **present** in a **sample of material**, or what **isotopes** are **present** in an **element**
- used to **determine isotopic composition** of an element - tells you **which isotopes** are **present** in an element and **percentage of each isotope** present
- during mass spectrometry, **sample** is **bombarded with high-energy electrons** or **UV light**
- this **knocks out** or **removes electrons**, **leaving atom** with an **overall positive charge**
- all atoms can be turned into **positively charged ions** by this method, even elements that would not normally become positively charged
- a **sample** of **carbon** that contains **two isotopes**, carbon-12 and carbon-13, will show **two positive ions**, each with a **different mass**
- **isotopes** - **both** have **six protons**, but will either have **six neutrons** (carbon-12) or **seven neutrons** (carbon-13)
- **positive ions** in sample **accelerated through** an **electric field** so they all **move** at **high speeds**
- then pass through **magnetic field** where they **undergo deflection** according to their masses
- **lighter ions deflected more** by the magnetic field; **heavier** ions deflected **less**

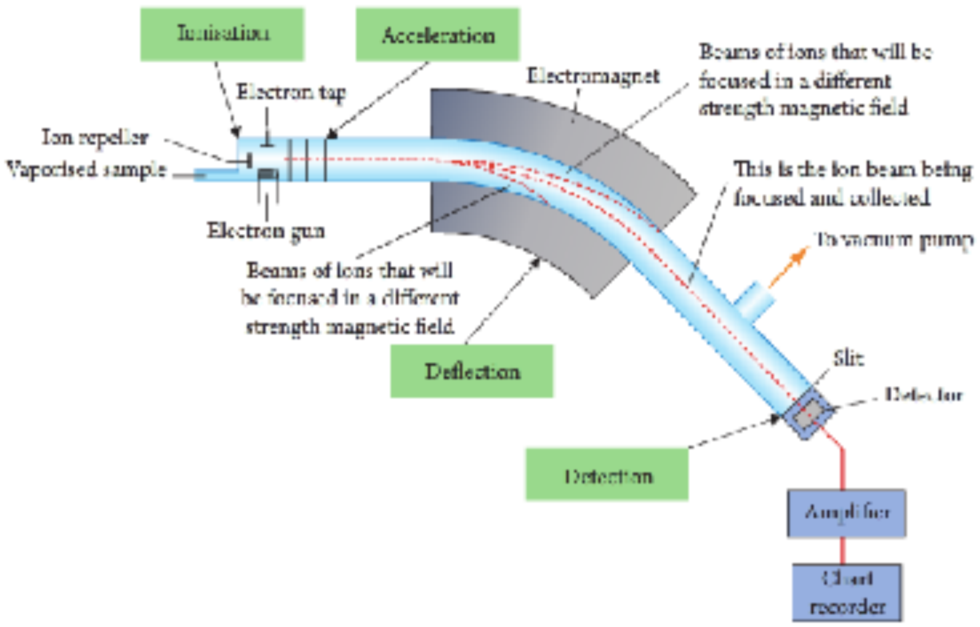


Figure C1.25
Deflection of different mass ions in a mass spectrometer

A quantitative tool

- **detectors measure** the **amount of ions** that **strike them**
- this info is transformed into **graphical form** called a **mass spectrum**
- this is a graph that shows the **mass of** the **ions** that are **present** and their **relative abundance**

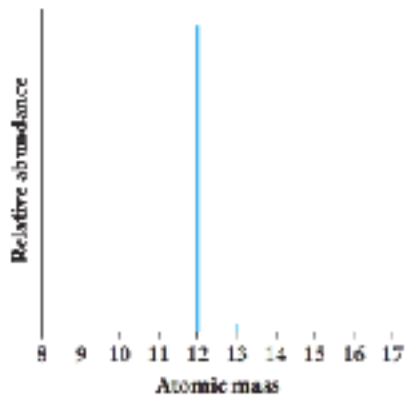


Figure C1.26 ▲
Mass spectrum of carbon isotopes

This clearly shows that an ion with an atomic mass of 12 is present in the greatest concentration and there is a small amount of an ion with an atomic mass of 13

QUESTION SET 1.7

Remembering

1. Describe briefly the process of atomic absorption spectroscopy

Element being analysed is determine. An electric current is passed through a gaseous sample of the element. Light from lamp of same element passes through the vaporised sample and is focused through a slit, then enters a monochromator. Detector measures intensity of light.

2. Explain how you would construct a calibration curve for the process of atomic absorption spectroscopy

A number of known concentrations of the element are prepared and their intensities are measured, Then a calibration curve of concentration against absorbance value is plotted. Absorbance value is on the vertical axis, concentration of element is on the horizontal axis. You can then compare another sample and determine it's concentration once its absorbance is measured.

3. What is the name of the graph formed during the process of mass spectroscopy

Mass spectrum

Understanding

4. Explain why the lamp in atomic absorption spectroscopy is made from the same element as the element being tested

When the lamp is made of a single element, then the list emitted has the same unique set of wavelengths as the element being tested allowing that element to absorb the light. Other element's electrons wont be able to absorb the light as it has different energy levels.

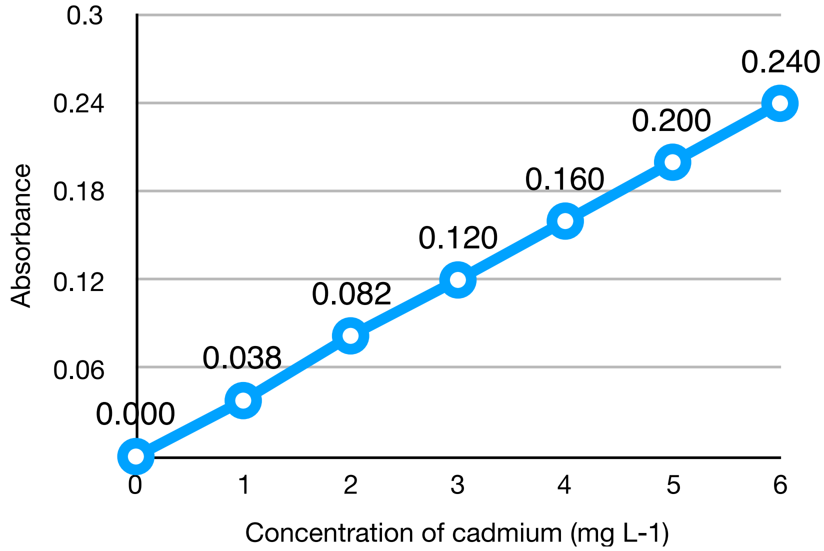
5. Explain why isotopes of different mass can be separated by a mass spectrometer

When the sample passes through the magnetic field it undergoes deflection. The heavier ions are deflected less than the lighter ions to show the abundance of the different isotopes present. Deflects the ions through a magnetic field based on the mass-to-charge ratio of the ion.

Analysing

6. Cadmium is useful in small amounts, but dangerous in large amounts. A sample of paint was tested for its cadmium content. Samples of known concentration of cadmium were analysed by atomic absorption spectroscopy and the results were obtained.

a. Construct a calibration curve for the known concentrations of cadmium



b. From the curve, determine the concentration of cadmium in the sample of paint

2.7 mg L^{-1}

7.

a. identify the isotopes present in this element

90, 91, 92, 94, 96

b. create a table showing the isotopes and their relative abundance

90	50%
91	10%
92	20%
94	15%
96	5%

c. calculate the relative atomic mass of this element and hence identify this element

mass number = (50 x 90) + (10 x 91) + (20 x 92) + (15 x 94) + (5 x 96) / 100

Zirconium relative atomic mass = 91.4

Reflecting

8. Identify some ways that atomic absorption spectroscopy and mass spectroscopy can help us learn more about what elements are in materials, or how we can identify them

They help us determine the abundance of different isotopes in elements, and the concentration of elements in a material through absorption of light and wavelength emitted.

CHAPTER CHECKLIST

- An **atom** is made up of a **nucleus** containing **positively charged protons**, **neutral neutrons**, and **negatively charged electrons** in regions of space called **energy levels** surrounding the nucleus
- **Elements** are substances composed of **one type of atom** and are represented by symbol
- The **atomic number** of an atom indicates the **number** of **protons** and **electrons**; the **mass number** indicates the **total number** of protons and neutrons in the atom
- Atoms are held together by **forces of attraction between** the **positive nucleus** and **negative electrons** surrounding the nucleus
- A **stable nucleus** is held together by the **balance** of **repulsive forces between protons** and the **attractive strong nuclear force** between **all particles** in the nucleus
- **Isotopes** of an element have the **same number** of **protons**, but a **different number** of **neutrons**. They may be **stable** or **unstable**, in which case they **undergo Radioactive decay**
- **Relative atomic mass** is used to **compare** the **masses** of **atoms** and **elements**. It is dependent on the **relative abundance** of an **element's isotopes** on Earth
- The **periodic table** is arranged in order of **increasing atomic number** and in **groups** and **periods**
- **Electrons** are **arranged** in **energy levels** according to specific rules. The **final arrangement** is called an **electron configuration**. This arrangement can be represented in a variety of different **visual ways**
- **Movement of electrons** between **energy levels** leads to **analysis** of elements through **examination** of the **light** they **produce** as **spectra**
- **Atomic absorption spectroscopy** allows determination of the **concentration** of an element
- **Mass spectrometry** can be used to determine the **isotopic composition** of an element

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CHAPTER GLOSSARY

- **Absorbance** - a measurement taken by a machine that compares the light passing into a substance with that exiting and gives us a value
- **Actinoids** - the period of the periodic table that, with the lanthanides, make up the f block
- **Alkali metals** - the common name of the elements found in Group 1 of the periodic table
- **Allotrope** - a different physical form of the same element
- **Alpha particle** - a particle containing two protons and two neutrons, sometimes called a helium nucleus
- **Atom** - the fundamental particle of matter; is composed of protons, neutrons, and electrons
- **Atomic absorption spectroscopy** - an analytical technique for determining the unknown concentration of an element based on the amount of light it absorbs
- **Atomic number** - the number of protons in an atom
- **Atomic orbital** - the region of space around an atom that has a specific shape and may contain a maximum of two electrons
- **Atomic orbital diagram** - a diagram showing the space electrons occupy in one of 4 orbitals - s, p, d and f
- **Atomic radius** - the distance from the nucleus to the boundary of the cloud of electrons surrounding it
- **Calibration curve** - a graph constructed during atomic absorption spectroscopy that plots known concentrations against the absorbance values, used to determine the concentration of an unknown substance
- **Chemical property** - a property of a substance relating to its ability to change to new substances during chemical reactions
- **Detector** - a device used to measure light or particles, found in both atomic absorption spectroscopy and mass spectrometry processes
- **Electron** - a negatively charged particle found in energy levels around the nucleus of an atom
- **Electron affinity** - the ability of an atom in the gaseous state to accept an electron and form a negative ion
- **Electron charge cloud diagram** - a visual representation of the region of space around a nucleus where an electron might be found
- **Electron configuration** - the arrangement of electrons around an atom in their energy levels
- **Electron shell diagram** - a visual representation of electrons in the energy levels around the nucleus
- **Electronegativity** - the relative ability of an atom to attract electrons
- **Electrostatic attraction** - a force that pulls particles together when they have an opposite charge
- **Electrostatic repulsion** - a force that pushes particles apart when they have an identical charge
- **Element** - a pure substance made up of atoms of the same atomic number
- **Energy level** - a region of the atom in which electrons of the same energy can be found
- **Excited state** - when an electron is in a higher energy level than the ground state due to absorption of energy
- **Ground state** - when all the electrons of an atom are in their lowest possible energy levels
- **Group** - the vertical columns in the periodic table that gives information of number of valence shell electrons and trends between atoms
- **Ion** - a charged atom, either positive from losing electrons, or negative from gaining electrons
- **Ionisation energy** - the amount of energy needed to remove an electron from a neutral atom when it is a gas

- **Isotopes** - different forms of an element with the same number of protons but different number of neutrons
- **Isotopic composition** - the number and amount of isotopes within a sample of an element
- **Lanthanoids** - period of the periodic table that, along with actinoids, make up the f block
- **Line emission spectrum** - a pattern of lines showing the component wavelengths in light
- **Mass number** - the total number of protons and neutrons in an atom
- **Mass spectrometry** - an analytical method that uses the different masses of particles to measure their relative abundance in a sample
- **Mass spectrum** - a graph produced during mass spectroscopy that shows the mass and relative abundance of substances present
- **Metalloid** - an element that has properties of both metals and non-metals
- **Monochromator** - a device used in atomic absorption spectroscopy to select light of a single wavelength
- **Nanotechnology** - a branch of science dealing with particles in the range of 1-100 nm
- **Neutron** - a neutral particle found in the nucleus of an atom
- **Nucleus** - a region of the atom containing all the protons and neutrons; it occupies only a small part of the volume of the atom but contains most of the mass
- **Period** - a horizontal row of elements in the periodic table that gives information on the number of energy levels occupied by electrons in an atom
- **Periodic table** - a chart of the elements arranged in increasing atomic number; it is organised into groups and periods to show trends in the elements
- **Physical property** - an observable feature of a substance that can be measured without changing the identity of the substance, such as colour, density, and hardness
- **Proton** - a positively charged particle found in the nucleus of an atom
- **Quantitative analysis** - analysis that measures values such as amount, concentration, or volume, rather than just identifying the substance
- **Radioactive decay** - the spontaneous disintegration of an atom due to instability in the nucleus, during which particles or electromagnetic radiation are released
- **Reactivity** - the likelihood of an element or substance undergoing a chemical reaction
- **Relative atomic mass** - the mean mass of an element that takes into account the isotope masses and the relative abundance on Earth; it is measured against carbon-12
- **Spectroscope** - a device used to separate light into its component wavelengths
- **Spectroscopy** - the branch of chemistry involving absorption and emission of light from substances
- **Strong nuclear force** - an attractive force that exists between particles in the nucleus; it is a short-range force acting only on adjacent particles
- **Subshell** - a part of an energy level that contains orbitals of the same energy
- **Synthetic element** - element that does not exist in nature, but has been made in the laboratory
- **Transition elements** - elements found between groups 2 and 13 in the periodic table, also known as the D-block elements
- **Ultraviolet light** - invisible, high-energy, high-frequency light of wavelengths 10 nm to 400 nm
- **Valence shell** - the outermost shell of an atom that contains electrons
- **Vaporised** - when a substance is heated so that it turns into its atomic form
- **Wavelength** - a property of light related to the length of the wave, which can give properties of light such as colour

Chemistry ATAR

CHAPTER REVIEW QUESTIONS

Remembering

1. Define

a. orbital
the region of space around a nucleus that has a specific shape and can hold a maximum of two electrons

b. allotrope
a different physical form of the same element

c. isotope
different forms of an element with the same number of protons but a different number of neutrons

d. energy level
a region of an atom in which electrons of the same energy can be found

e. calibration curve
a graph constructed during atomic absorption spectroscopy that plots known concentrations against the absorbance values

f. electronegativity
the relative ability of an element to attract electrons

g. excited state
when an electron is in a higher energy level due to the absorption of energy

2. Compare the sizes and charges of the three particles found in an atom

Protons - positively charged, relative mass 1. Neutrons - no charge, relative mass 1. Electrons - negatively charged, relative mass 1/1800

3. What information an be determined by the following in the periodic table

a. the group an element is in
gives information about the number of valence shell electrons in the element

b. the period an element is in
gives information about the number of energy levels occupied by the electrons in the element

4. How many valence electrons are in the following elements

a. oxygen
6

b. chlorine
7

c. magnesium
2

d. selenium
6

5. Describe how trends in the atomic radius can be determined from the periodic table

Atomic radius increases down the groups of the periodic table and decreases from left to right across a period - more energy levels, less attraction between electrons and protons in nucleus increasing from left to right

6. Copy and complete the following table, using your knowledge about trends in the periodic table.

Element pair	Highest ionisation energy	Highest electronegativity	More metallic character
carbon and fluorine	fluorine	fluorine	carbon
sodium and lithium	lithium	lithium	sodium
silicon and nitrogen	nitrogen	nitrogen	silicon
beryllium and boron	boron	boron	beryllium

Understanding

7. An element has 14 electrons. Explain how you would fill up the energy levels to gain the final electron configuration

2, 8, 4. The first 2 electrons fill the first shell, then the next 8 fill the second shell, the remaining 4 are in the third shell.

8. Explain why electronegativity increases from left to right across the periodic table

Electronegativity increases from left to right because as you go across the periods, the amount of protons increase meaning there is a stronger attraction between the positive nucleus and the negative electrons. This decreases the atomic radius and increases an atoms ability to attract electrons.

9. Explain why light is emitted from an atom when energy is applied to it in the form of heat in a flame test

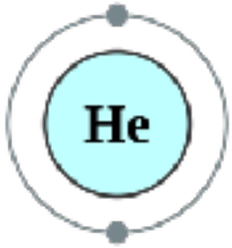
Because the atom absorbs the energy causing the electrons to move up to higher energy levels releasing light as the atom enters the excited state.

10. A sample of copper(II) nitrate is compared to a sample of barium nitrate during a flame test experiment. Explain why they emit light of different colours

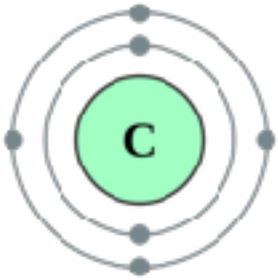
Because they both have different energy levels so when the electrons go to these higher levels they release different wavelengths of light causing different colours.

11. Draw electron shell diagrams to represent the arrangement of electrons in the following elements

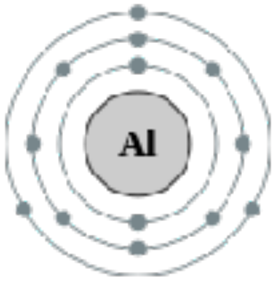
a. Helium



b. Carbon



c. Aluminium



12. Write electron configurations for the following elements

a. Boron
   $1s^2, 2s^2, 2p^1$

b. Sulfur
   $1s^2, 2s^2, 2p^6, 3s^2, 3p^4$

c. Lithium
   $1s^2, 2s^1$

d. Vanadium
   $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^3, 4s^2$

13. Identify the following elements with the following electron configurations

a. 2, 6
   oxygen

b. 2, 8, 8
   argon

c. 2, 8, 15, 2
   cobalt

Applying

14.

a. Copy and complete the following table

Element	Atomic number	Mass number	Number of protons	Number of neutrons
Carbon-14	6	14	6	8
Chlorine	17	35	17	18
Iron	26	56	26	30
Copper	29	64	29	35
Carbon-13	6	13	6	7

b. Identify any isotopes from the table and explain why they are considered to be isotopes

Carbon-14 and carbon-13 are isotopes as they have the same number of protons/ atomic number, but a different mass number/ number of neutrons

15. Use atomic representation to show the following information

a. Aluminium with atomic number 13 and mass number 27

$^{27}_{13}Al$

b. Tin with atomic number 50 and mass number 119

$^{119}_{50}Sn$

c. Oxygen with 8 protons and 8 neutrons

$^{16}_{8}O$

d. Iodine with 53 protons and 74 neutrons

$^{127}_{53}I$

e. Rubidium with mass number 85

$^{85}_{37}Rb$

16. Silicon has three isotopes: silicon-28 with an abundance of 92.23%, silicon-29 with an abundance of 4.68% and silicon-30 with an abundance of 3.09%. Calculate the relative atomic mass of silicon.

mass number = (92.23 x 28) + (4.68 x 29) + (3.09 x 30) / 100

Silicon relative atomic mass = 28.11

17. State and explain the identity of the unknown sample

The unknown is helium because its emission spectra is the same as the known helium wavelength

18. The level of zinc in some food was labelled on the container. Students analysed samples of the food by atomic absorption spectroscopy to determine whether the level on the container was correct. Samples of known concentration of zinc were analysed and the following data were obtained.

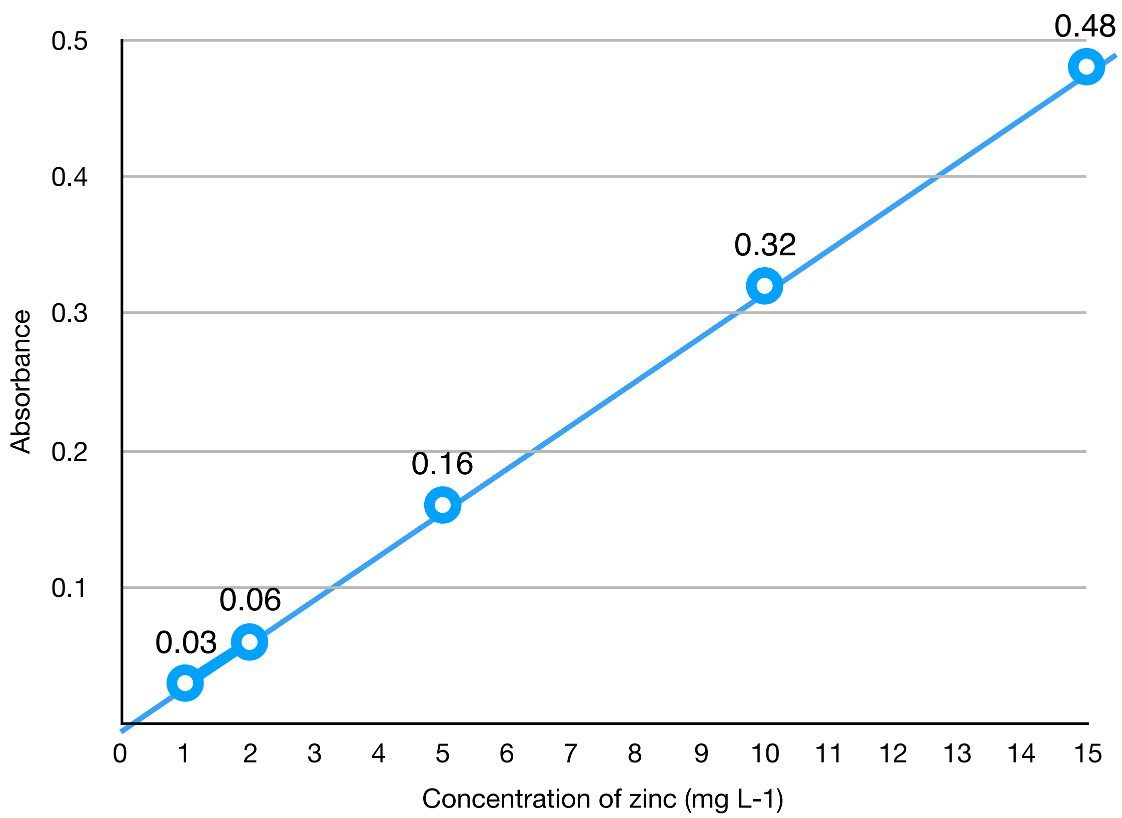
a. Explain what the lamp would have been made from for this analysis

The lamp would've been made from zinc as it needs to be the same as the element being analysed

b. Explain why the presence of a metal such as calcium in the food would not have interfered with this process

Because only elements with the same wavelengths and energy level can absorb the light emitted by the lamp in the process. This means only the zinc would've been absorbed and not other metals.

c. Construct a calibration curve with the concentration of zinc on the horizontal axis and the absorbance on the vertical axis



d. The sample of food gave an absorbance reading of 3.6. From the graph, determine the concentration of zinc in the food
The concentration of zinc is 12mg L^{-1}

e. The label on the container stated that the level of zinc in the food did not exceed 7.5 $molL^{-1}$. Explain whether this statement is true
This statement is false, it contains 12ppm which exceeds the level on the label

19.

a. Explain why the different isotopes can be separated by a mass spectrometer
The different isotopes can be separated because they have different masses which gets deflected by different amounts in the magnetic field process when they are vaporised, which splits the different masses of ions up. The lighter ions get deflected more than the heavier ions.

b. How many isotopes were present in the element sample
5 isotopes

c. Which isotope was present in the highest concentration
Isotope 44

Reflecting

20. Explain why different representations exist to show how electrons are arranged around a nucleus

Electron shell diagrams show how many electrons are in each electron shell, electron charge cloud diagrams show the probability of electrons being found in a particular place in the atom and atomic orbital diagrams show how the orbitals appear around a nucleus.

Chapter 2: CLASSIFYING AND SEPARATING SUBSTANCES

2.1 CLASSIFYING MATTER

- all **matter** that **exists naturally** originally came from **atoms formed in stars**
- these atoms **combined** in different ways to **form Earth** and all its **materials**
- some materials found **naturally**, some are **synthesised**
- materials can be **classified** by how they're **used**, **properties** they have or **state** they're in
- can be classified by **type of substance** composed of, way these **substances** are **combined**
- are either **pure substances** that are made up of **one type of particle** and have **constant compositions**, or **mixtures** which are made up of **two or more pure substances** and have **variable compositions**

Heterogenous materials

- **mixture** - **matter** that contains two or more **different substances**
- can also have **different proportions** of the **same material**
- **heterogenous mixtures** - **non**-**uniform** mixtures that contain **physically separate materials**
- e.g. milk - fat globules suspended in water

Homogenous materials

- **homogenous materials** - have **uniform composition** throughout
- if you were to break a piece of homogenous material into smaller pieces and look at it under a microscope it would be impossible to distinguish one part of the material from another
- e.g. raw sugar, salt water and window glass

- only **one type of homogenous material** can be classified as a **mixture**; a **solution**
- **solutions** - consists of **solute** (generally **dissolved** material) in a **solvent** (**dissolving** material)
- because **solute** is **distributed throughout solvent** in extremely **small particles**, a solution **appears uniform throughout**

- **pure substances** - made up of only **one type of particle**
- **elements** - pure substances composed of only **one type of atom**, e.g. gold, carbon
- **compounds** - pure substances composed of **more than one type of atom chemically combined** in **fixed proportions**, e.g. water, carbon dioxide

2.2 PHYSICAL AND CHEMICAL PROPERTIES

- a pure substance has distance measurable properties that can be used to identify it
- properties of mixtures depend on the identity and relative amount of substances that make up the mixture

Physical properties

- can be determined **without changing chemical composition** of a substance
- e.g. melting point, boiling point
- strength, density, malleability,
- ductility, electrical conductivity, thermal conductivity
- solubility, state, hardness etc
- while **pure substances** may have **similar physical properties** and can be classified into broad grouping such as **metals** and **non-metals**, there are **always differences** that **allow individual substances** to be **identified**

Chemical properties

- relates to the **ability** of a **substance** to **react** and **form new substances**
- in determining chemical properties, **chemical composition** of **original** substance is **changed**
- e.g. decomposition by heat, effect of light
- reactions with water, acids, bases, oxygen etc
- **chemical properties** of substances used to **identify** and **distinguish** between them

Physical and chemical changes

- **physical changes** - changes in **physical properties** e.g. density, state and colour
- **no change** in **chemical composition** of the substance
- e.g. tearing paper, dissolving salt, freezing water

- **chemical changes** - change in which at least one **new substance** is **formed**
- **chemical composition** of **original** substance **changed**
- **new substance** formed has **different chemical** and **physical properties**
- type of chemical change a substance undergoes relates to its **chemical properties**
- e.g. burning, digestion, fermentation

- chemical changes also referred to as **chemical reactions**
- can determine a chemical reaction has occurred if:
- a solid (precipitate) has formed
- a gas is produced
- there is a colour change
- there is a significant change in temperature
- an insoluble solid disappears

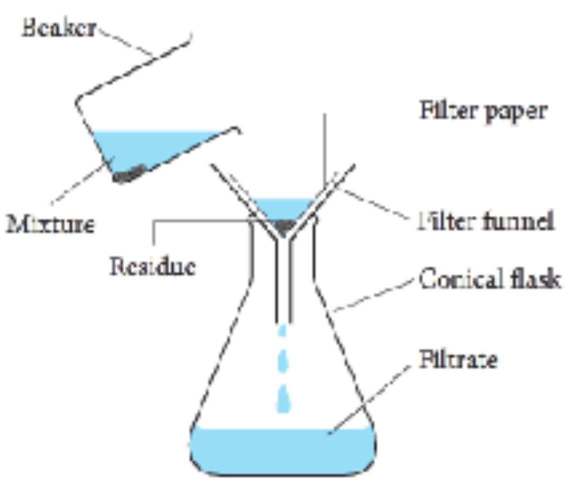
2.3 SEPARATING MIXTURES

Separation method	Typical mixture separated by this method	Property used in separation
electrostatic attraction	mixtures of electrostatic and non-electrostatic materials	difference in electrical charge
filtration	mixtures of insoluble solid and liquids	difference in state and size of particles
fractional distillation	mixtures of liquids	significant but small difference in boiling points
magnetic separation	mixtures of magnetic and non-magnetic material	difference in attraction to a magnetic field
separating funnel	mixtures of immiscible (undissolved) liquids	difference in densities
sieving	mixtures of solid or solids and liquids	difference in particle size
simple distillation	mixtures of liquids or liquids and solids	big difference in boiling points
vaporisation (evaporation or boiling)	solutions containing dissolved solids	liquid has a much lower boiling point that dissolved solids

Separation by difference in particle size

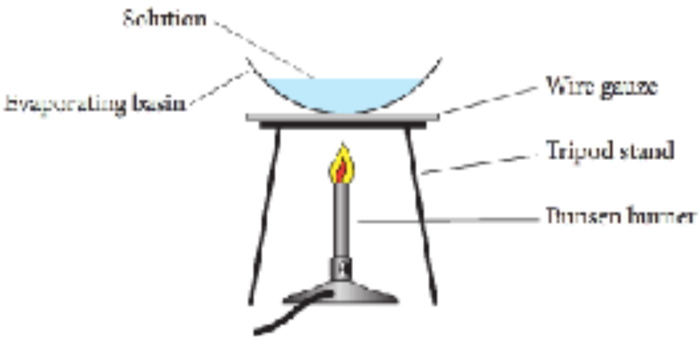
- **sieving** - one way of **separating mixtures** of solids, or solids and liquids with **different sized particles**
- mixture is poured through a sieve and **particles** that are **smaller than sieve pass through** while **larger particles** are **trapped**

- **filtration** - **separation** technique that also depends on **particle size**
- more commonly used for **mixtures of solids and liquids**, particularly when **solid particles** are quite **small**
- **liquid** or **solution** is **poured into** and **passes through filter paper**, and **solid** or **residue** is **trapped** by paper
- **filtrate** - **liquid** or **solution** that passes **through**
- also used to separate larger particles suspended in air

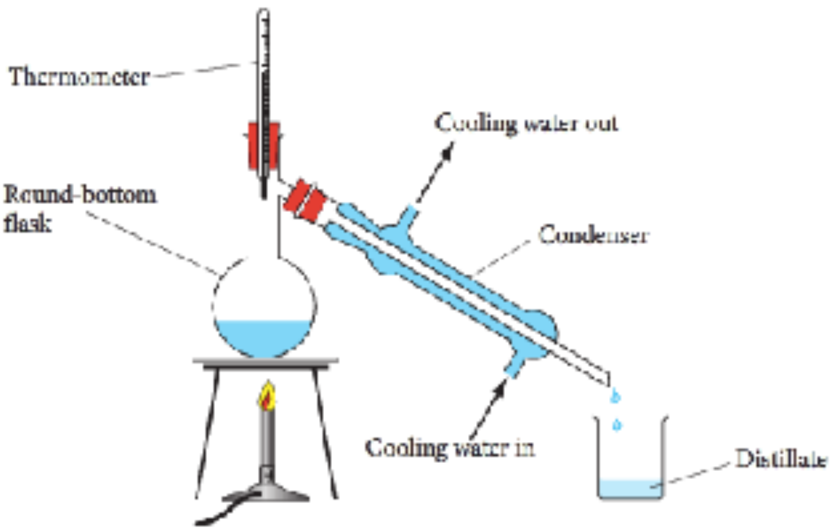


<u>Separation by difference in boiling point</u>

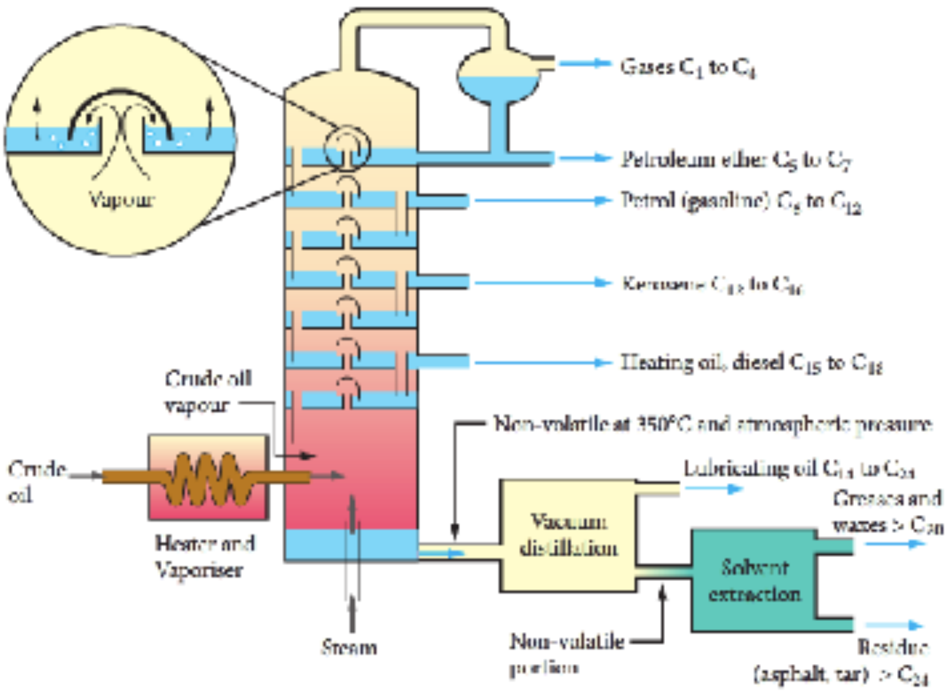
- **vaporisation** - most commonly used to **retrieve** a **solid** that has been **dissolved in** a **liquid** (i.e. when there is a **solution**)
- **liquid component** of solution (**solvent**) is converted to **vapour** either by **boiling** solution or allowing it to **evaporate**, **leaving behind** dissolved **solid** (**solute**)
- boiling is a much quicker process than evaporation
- chemists frequently use boiling to **remove solvent from solution** to obtain a **dry solute**
- **evaporating to dryness**
- effective when **dissolved solid** is **desired product**, **does not recover liquid**



- **simple distillation** - used for **separating** two or more **liquids** or **separating liquid from solids** in a solution **retrieving liquid component**
- relies on a **difference** of at least **50°c** in **boiling point** between components to obtain an effective separation
- mixture to be separated is placed in a round bottom flask and **heated to boiling**
- **vapour rises** up neck of flask and then **flows** into **water cooled condenser**
- **vapour condenses** back to a **liquid** (**distillate**) and is collected in a beaker
- liquid with **higher boiling point** and any **solids** are **left**

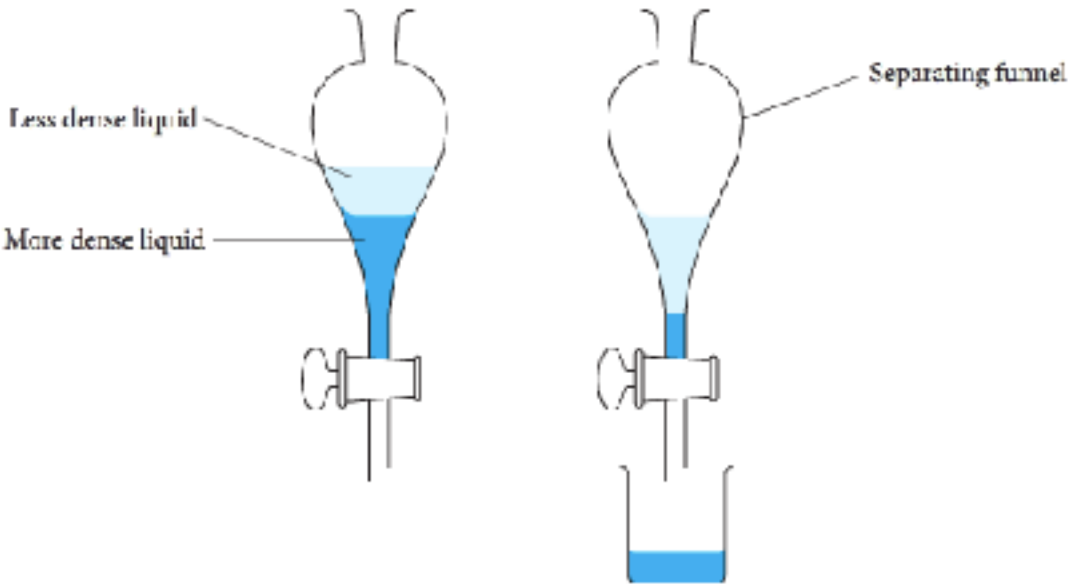


- **fractional distillation** - used to **separate liquids** that have **boiling points close together**
- mixture is **heated** and **components** or **fractions** with **different boiling points rise** up **fractionating column** to **different heights**
- component with **lowest** bp at **bottom** of column, **highest** bp at **top**
- used for separating crude oil into its components at oil refineries
- cryogenic air separation to obtain oxygen, nitrogen and argon from liquid air



Separation by density and solubility

- **separating funnel** - used to **separate two immiscible liquids**, e.g. oil and water
- immiscible liquids separate into **two layers**, **less dense on top** of more dense
- **not soluble** in each other
- when stopcock at base of funnel is opened, **denser component runs into beaker** leaving **less dense component in funnel**



- solids of **different densities** often separated by using **running water** and **agitation**
- e.g. panning for gold
- **lighter particles** are **carried away** by running water and **heavier gold sinks** to bottom of pan

- a **mixture** of **solids** with **similar sized particles** can be easily separated if the solids have different solubilities in a solvent
- add sufficient solvent to ensure entire soluble component is dissolved
- filter mixture to separate soluble and insoluble components
- evaporate solvent to retrieve soluble component

<u>Separation by magnetism and electrostatic attraction</u>

- **magnetic separation** - uses **degree** to which a substance is **attracted** to a **magnetic field**
- **strongly magnetic** materials such as iron, cobalt and nickel can be **removed** from **low** or **non**-**magnetic** materials by **low**-**intensity magnetic separator**
- used in mining industry

- **electrostatic separation method** - separates particles on the basis of **difference** in **electrical charge**
- as a mixture is brought into an **electrical field**, differently **charged** particles will be **attracted or repelled** and **follow different paths** so they can be **caught separately**
- used in industrial plants that process mineral sands containing zircon, rutile and monazite

3.4 NAMES AND FORMULAS OF IONIC COMPOUNDS

- name/ formulas of **ionic compounds** composed of **2 elements** - **positively charged ion** is always listed **first** and **negatively charged ion** listed **second**
- name of **positive** ion same as **name of element** from which is was formed
- name of **negative** ion, **end of non-metal parent element** replaced with -***ide***
- e.g. chlorine becomes chlor*ide*, oxygen becomes ox*ide*, hence, the names sodium chlor*ide*, magnesium ox*ide*

- **transition metals** have slightly **different electron structures** from other metals
- many transition metals show **more than one possible charge**

Ion	Fe^{2+}	Fe^{3+}	Cu^{+}	Cu^{2+}
Current naming convention	Iron(II)	Iron(III)	Copper(I)	Copper(II)
Former name	Ferrous	Ferric	Cuprous	Cupric

- two different ionic compounds formed between iron and chlorine
- iron(II) chloride and iron(III) chloride - particular compound present indicated by $FeCl_2$ or $FeCl_3$

- In many **ionic compounds**, the positive, negative (or both) ion consists of **two or more atoms** that are **strongly bonded together** and **act as a single entity**
- these ions are called **polyatomic ions**
- **outer-shell electrons** have **partially merged** because ions are **sharing outer shell electrons**
- charge on polyatomic ions is spread over whole ion

Name of ion	Formula	Valency	Example of a compound
Ammonium	NH_4^+	+1	Ammonium chloride
Hydroxide	OH^-	-1	Iron(III) hydroxide
Nitrate	NO_3^-	-1	Silver nitrate
Sulfate	SO_4^{2-}	-2	Copper(II) sulfate
Carbonate	CO_3^{2-}	-2	Calcium carbonate
Phosphate	PO_4^{3-}	-3	Sodium phosphate

Formulas for ionic compounds

- when determining formulas for ionic compound, there is one simple rule
- ionic compounds have **no net charge**
- this means total number of **positive charges** = total number of **negative charges**
- need to determine **ratio** of ions that will achieve this

QUESTION SET 3.4

Remembering

1.

d. What is the overall charge on an ionic compound

No overall net charge

e. How is this achieved?

Through equal number of positive and negative ions

Understanding

2. Write the name and give the formula of ions of the following elements

a. Bromide

Bromide Br^-

b. Sulfur

Sulfur S^{2-}

c. Barium

Barium Ba^{2+}

d. Potassium

Potassium K^+

e. Nitrogen

Nitrogen N^{3-}

3. Draw the electron dot formulas for the elements and ions in questions 2a, c and e

a. Bromide

Br

b. Barium

Ba

c. Nitrogen

N

Applying

4. Write the names of the following ionic compounds

a. KI

Potassium iodide

b. $BaCl_2$

Barium chloride

c. CaH_2

Calcium hydride

d. PbO_2
Lead(IV) oxide

e. Na_3PO_4
Sodium phosphate

f. $Zn(NO_3)_2$
Zinc nitrate

5. Give the formulas of the following ionic compounds

a. Magnesium nitride
Mg_3N_2

b. Aluminium oxide
Al_2O_3

c. Mercury(II) sulfide
HgS

d. Ammonium hydroxide
NH_4OH

e. Copper(I) carbonate
Cu_2CO_3

f. Zinc phosphate
$Zn_3(PO_4)_2$

Applying

6. Deduce what charge X must have in each of the following compounds.

a. XOH
+1

b. XI_2
+2

c. XNO_3
+1

d. X_2SO_4
+1

e. LiX
-1

f. ZnX_2
-1

g. Al_2X_3
-2

3.6 NAMES AND FORMULAS OF COVALENT COMPOUNDS

- **valency** of an element is an indication of the **number of bonds** it can form
- transition metal - **non-metallic** elements can display **more than one valency** in covalent compounds
- **names** of covalent compounds need to provide an **indication of valency**

Naming covalent compounds

- covalent compounds made up of **two elements**

1. use element name for first element, change end of **second** name to **ide**; e.g. hydrogen fluoride
2. **first** named element is the one that is **further to the left** in periodic table
3. if both elements are in the **same group**, the one **lower down** the group is named **first**
4. exception when oxygen is bonded to Cl, Br or I - oxygen named last
5. **number of atoms** of each type is given by using the **prefixes** in front of each part of the name (though mono may be omitted from the first named element) e.g. CO is carbon monoxide, CO_2 is carbon dioxide and N_2O_5 is dinitrogen pentoxide

Prefix	mono	di	tri	tetra	penta	hexa	hepta	octa	nona	deca
Number of atoms	1	2	3	4	5	6	7	8	9	10

- sometimes, compounds referred to by their common names rather than systematic name
- e.g. H_2O, dihydrogen monoxide is called water; NH_3, nitrogen trihydride is called ammonia

Writing formulas for covalent compounds

- order is given by name, and prefix of element becomes subscript for that element in the formula
- e.g. diphosphorus pentoxide is P_2O_5

QUESTION SET 3.6

Remembering

1. Explain how to determine which element is written first in the compound

first named element is the one that is further to the left in periodic table

2. Write the formula of:

a. Sulfur dioxide

SO_2

b. Dinitrogen pentoxide

N_2O_5

c. Carbon tetrachloride

CCl_3

d. Nitrogen trifluoride

NF_3

e. Silicon tetrabromide

$SiBr_4$

3. Name the following compounds:

a. N_2O

dinitrogen oxide

b. NCl_3

nitrogen trichloride

c. SO_3

sulfur trioxide

d. H_2S

dihydrogen sulfide

e. N_2O_4

dinitrogen tetroxide

Chemistry ATAR

GENERAL WORD EQUATIONS

Name	Equation	Example
combustion	fuel + oxygen gas -> oxide(s) + energy	$CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$ + energy
neutralisation	acid + base -> salt + water	
displacement		
displacement	acid + (H) carbonate -> salt + water + carbon dioxide	
decomposition (heating)	carbonate + heat-> oxide + carbon dioxide (+ water)	
precipitation	cation (aq) + anion (aq) -> insoluble metal salt (s)	
metal/ metal ion displacement	more active metal + less active metal ion -> more active metal ion + less active metal solid	

"Salt" Ionic compound with a metal (or NH_4^+) cation

Types of chemical reactions

Decomposition of a carbonate by heating
Decomposition of a carbonate with an acid
Oxidation of a metal
Reaction of a reactive metal with a dilute acid
Precipitation reactions
Metal displacement reactions
Neutralisation reaction (reaction of an acid and a base)

4.1 CHEMICAL REACTIONS

Chemical equations

- chemical reaction represented by chemical **equation**
- **words** or **formulas**
- **reactants** on **left** side, **product** on **right** side
- e.g. photosynthesis - carbon dioxide + water -> glucose + oxygen
- carbon dioxide and water - reactants
- glucose + oxygen - products

Balancing chemical equations

- **numbers written in front** of chemical formulas - balance equation - **same number** of **atoms** of each element on **each side**
- equations written as **lowest whole number ratio** between reactants and products
- ensures **law of conservation of mass** is maintained
- **states** for each reactant and products included
- (**s**) solid, (**l**) liquid, (**g**) gas, (**aq**) aqueous solution
- chemist use balanced chemical equations to **summarise info** about chemical reactions
- these equations concisely communicate info about **reactants**, **products** and **numbers of atoms** in each element present

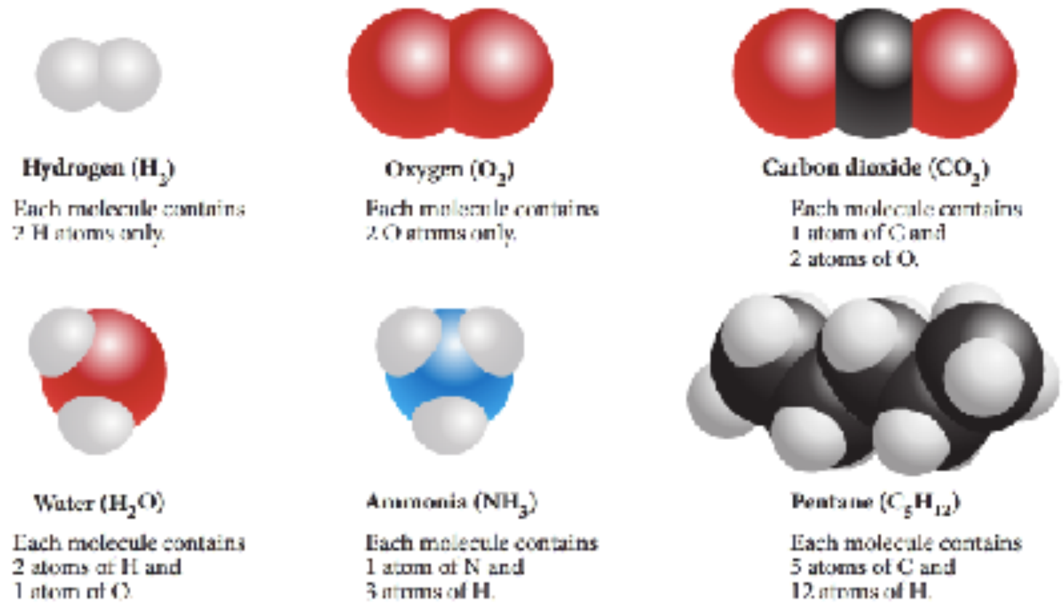
- $Mg + HCl \rightarrow MgCl_2 + H_2$
- balanced: $Mg + 2HCl \rightarrow MgCl_2 + H_2$
- include states: $Mg\ (s) + 2HCl\ (aq) \rightarrow MgCl_2\ (aq) + H_2\ (g)$

5.1 RELATIVE MASS OF ATOMS AND SUBSTANCES

- **relative atomic mass** of an atom is **mass relative** to that of **carbon-12 atom**
- **mass of carbon** considered to be exactly **12**
- all others compared to this

Relative mass of substances

- chemical **symbols**/ **formulas** - short-hand representations for **elements**/ **compounds**
- also represent **group of atoms** or **formula units**
- **relative atomic mass** describes **mass** of an **atom**
- **relative molecular mass M_r** describes **mass** of **one molecule** of **molecular substance** on **scale** which mass of carbon-12 isotope exactly 12
- M_r of an element or compound calculated by **adding** the **relative atomic mass** of **all component atom** of molecule



- not all pure substances exist as molecules - **ionic substances** - **relative formula mass**
- same as calculating relative molecular mass

WORKED EXAMPLE 5.1

Calculate the relative atomic mass of ethane, C_2H_6

identify number of each atom type
multiply number of each atom by their relative atomic mass
add masses of each element to obtain compound relative atomic mass

Mass C = 2 x 12 = 24
Mass H = 6 x 1 = 6
Relative atomic mass of C_2H_6 is 30

a. Phosphorus (P_4)

Mass P = 30.974
P_4 = 4(30.974)
M_r (P_4) = 123.896

b. Carbon dioxide (CO_2)

Mass C = 12.009
Mass O = 15.999
CO_2 = 12.009 + 2(15.999)
M_r (CO_2) = 44.007

c. Nitric acid (HNO_3)

Mass H = 1.008
Mass N = 14.006
Mass O = 15.999
HNO_3 = 1.008 + 14.006 + 3(15.999)
M_r (HNO_3) = 63.011

d. Glucose ($C_6H_{12}O_6$)

Mass C = 12.009
Mass H = 1.008
Mass O = 15.999
$C_6H_{12}O_2$ = 6(12.009) + 12(1.008) + 6(15.999)
M_r ($C_6H_{12}O_2$) = 180.144

Relative formula/ molecule mass

Silicon Dioxide
Mass Si = 28.084
Mass O = 15.999
$M_r (SiO_2)$ = 28.084 + 2(15.999)
$M_r (SiO_2)$ = 60.082

Sulphuric acid
Mass H = 1.008
Mass S = 32.059
Mass O = 15.999
$M_r (H_2SO_4)$ = 2(1.008) + 32.059 + 4(15.999)
$M_r (H_2SO_4)$ = 98.071

Potassium Permanganate
Mass K = 39.098
Mass Mn = 54.938
Mass O = 15.999
$M_r (KMnO_4)$ = 39.098 + 54.938 + 4(15.999)
$M_r (KMnO_4)$ = 158.032

S_8
Mass S = 32.059
$M_r (S_8)$ = 8(32.059)
$M_r (S_8)$ = 256.472

5.2 PERCENTAGE COMPOSITION

- chemical formula of **compound** gives info about elements present and **ratio** which **atoms** of those **elements** are **present**
- (H_3PO_4) H, P and O present in ration 3:1:4
- **ratio of atoms** is **NOT** same as **ratio of masses of atoms** - atoms have different relative atom masses
- **percentage composition** of a **compound** is **percentage by mass** of **each different element** in compound

Calculating percentage composition

- calculated from **chemical formula** and **relative atomic masses** of each element in compound
- is independent of how much of the compound there is

WORKED EXAMPLE 5.3

Percentage composition of Aluminium Oxide (Al_2O_3)

Mass of Al = 2 x 27.0 = 54.0
Mass of O = 3 x 16.0 = 48.0
Formula mass of Al_2O_3 = 54.0 + 48.0 = 102.0
%Al = (54.0/ 102.0) x 100 = 52.9%
%O = (48.0/ 102.0) x 100 = 47.1%

Percentage composition of Methane (CH_4)

Mass of C = 12.0
Mass of H = 4 x 1.0 = 4.0
Formula mass of CH_4 = 12.0 + 4.0 = 16.0
%C = (12.0/ 16.0) x 100 = 75%
%H = (4.0/ 16.0) x 100 = 25%

Percentage composition of Sodium Chloride (NaCl)

Mass of Na = 22.99
Mass of Cl = 35.45
Formula mass of NaCl = 22.99 + 35.45 = 58.44
%Na = (22.99/ 58.44) x 100 = 39.34%
%Cl = (35.45/ 58.44) x 100 = 66.66%

Percentage composition of Calcium Cyanide ($Ca(CN)_2$)

Mass of Ca = 40.078
Mass of C = 12.011
Mass of N = 14.007
Formula mass of $Ca(CN)_2$ = 40.078 + 2(12.011) + 2(14.007) = 92.114
%Ca = (40.078 / 92.114) x 100 = 43.5%
%C = (24.022 / 92.114) x 100 = 26%
%N = (28.014 / 92.114) x 100 = 30.5%

5.3 THE AVOGADRO CONSTANT AND THE MOLE

The Avogadro constant

- chemist use relationship between mass and number of particles
- relative mass of elements of an atom devised by comparing them to mass of a carbon-12 atom
- 1 amu = 1/12th mass of one carbon-12 atom
- chemist chose number of particles = to mass in grams to mass of one atom in amu
- same number fits all elements - equal numbers of different atoms always have same mass ratio
- 6.022×10^{23} - Avogadro constant (N_A)
- Avogadro constant (N_A) - number of atoms (6.02×10^{23}) in exactly 12 grams of carbon-12 isotope
- is a scaling factors between macroscopic and microscopic observations of nature

The Avogadro constant and the mole

- chemist measure amount of substances in moles (mol) (n)
- mole is SI base unit representing chemical quantity of a substance
- a mole is the amount of substance containing 6.022×10^{23} particles of that substance

Converting between moles and number of particles

- number of moles (n) = number of particles/ number of particles per mole (N_A)
- N = number of particles / 6.022×10^{23}
- number of particles = n x 6.022×10^{23}

WORKED EXAMPLE 5.4

How many moles of magnesium are there in 1.45×10^{23} atoms of magnesium?

n(Mg) = $1.45 \times 10^{23} / 6.022 \times 10^{23}$
= 0.24 mol

How many moles of carbon are there in 3.3×10^{25} atoms of carbon?

n(C) = $3.3 \times 10^{25} / 6.022 \times 10^{23}$
= 54.8 mol

How many moles of water are there in 1.2×10^{22} molecules of water?

n(H_2O) = $1.2 \times 10^{22} / 6.022 \times 10^{23}$
= 0.199 mol

How many moles of sodium are there in 6.6×10^{21} ions of sodium?

n(Na^+) = $6.6 \times 10^{21} / 6.022 \times 10^{23}$
= 0.110 mol

5.4 MOLES AND MASS

- **1 mole** of any substance has a **mass equal** to the **relative** atomic, molecular or formula **mass** of that substance expressed in **grams**
- Molar mass (M) = M_r(g)
- e.g. relative atomic mass of ethane is 30.0, so the molar mass is 30g mol^{-1}

Converting between moles and mass

- number of moles = mass (g)/ molar mass (g mol^{-1})
- **n = m / M**
- **m = n x M**

WORKED EXAMPLE 5.8

How many moles of copper (II) sulphate ($CuSO_4$) are there in 12.2g of copper (II) sulphate

n = m / M
n = ?, m = 12.2g, M can be calculated
M($CuSO_4$) = M(Cu) + M(S) + 4 x M(O)
= 63.6 + 32 + (4 x 16)
M($CuSO_4$) = 156.6 g mol^{-1}
n($CuSO_4$) = 12.2 / 156.6
= 0.0779 mol

WORKED EXAMPLE 5.9

What is the mass of 0.75 mol of sodium hydroxide (NaOH)?

n = m / M
n(NaOH) = 0.75, m = ?, M can be calculated
M(NaOH) = M(Na) + M(O) + M(H)
= 23 + 16 + 1
M(NaOH)= 40 g mol^{-1}
m(NaOH) = n x M
= 0.75 x 40
= 30g

5.5 EMPIRICAL AND MOLECULAR FORMULAS

- **empirical formula** of any compound - **simplest whole number ratio** in which the **atoms** of the **elements** are present
- **ionic compounds** - **formula given** because these have an **infinite lattice** structure
- **molecular** substance states **actual number** of **each type** of **atom** present in molecule

- obtained from experiment
- determine **% composition**, apply **mole concept** - determine **ratio** of particles

5.6 CHEMICAL EQUATIONS, MOLES AND MASS

- **coefficients** of the species in the equations also **indicate molar ratio** of reaction
- **stoichiometry** - study of **amounts of reactants** and **products** in a chemical reaction
- if we know the **number of moles** of any species in the reaction, then we can use the **balanced equation** to work out the number of moles of all the other species in that reaction

- **chemical equations** can also be used to determine **relationship between masses** of reactants and products
- **The law of conservation of mass** -in a chemical reaction, mass is neither created nor destroyed. **total mass of product = total mass of reactants**
-