C1+

Transition elements are metals with similar properties which are different from those of the elements in Group 1. The have **higher melting points, densities, greater strength and greater hardness** than Group 1
Many transition elements have ions with different charges (e.g Mn^{2+} and Mn^{3+} ions), form coloured compounds and are useful as catalysts (e.g Iron in Haber cycle)

Nanoscience refers to structures that are 1–100 nm in size, of the order of a few hundred atoms.
Nanoparticles, are smaller than **fine particles** (**PM2.5**), which have diameters between 100 and 2500 nm (1×10^{-7} m and 2.5×10^{-6} m). **Coarse particles or dust** (**PM10**) have diameters between 1×10^{-5} m and 2.5×10^{-6} m. As the side of cube decreases by a factor of 10 the **surface area to volume ratio** increases by a factor of 10. Nanoparticles may have properties different from those for the same materials in bulk because of their high surface area to volume ratio. Smaller quantities are needed to be effective than for materials with normal particle sizes

Nanoparticles have many applications in medicine, in electronics, in cosmetics and sun creams, as deodorants, and as catalysts.
Concerns: Small enough to breathe in, could catalyse harmful reactions, toxic substances could bind to large SA.

% Yield = Mass of product actually made/ Maximum theoretical mass of product × 100
It is not always possible to obtain the calculated amount of a product because: • the reaction may not go to completion because it is **reversible** • some of the product may be **lost** • some of the reactants may react in ways different to the expected reaction

Atom economy (atom utilisation) is a measure of the amount of starting materials that end up as useful products.
It is important for sustainable development and for economic reasons to use reactions with high atom economy.
Relative formula mass of desired product / Sum of relative formula masses of all reactants × 100

The **concentration of a solution** can be measured in **mol/dm³** .
Amount = concentration × volume
If the volumes of two solutions that react completely are known and the concentration of one solution is known, the concentration of the other solution can be calculated.

Starting concentration, Final concentration

$$C_1 V_1 = C_2 V_2$$

Starting volume, Final volume

At a given temperature and **pressure**, one **mole** of any gas occupies the same **volume**.
Molar volume of any gas at room temperature and pressure (20ºC and 1 atmosphere pressure) is **24 dm³ . Volume = amount in mol × molar volume**

Titrations used to calculate the volumes of acid and alkali solutions that react with each other.
RP: determination of the reacting volumes of solutions of a strong acid and a strong alkali by titration.
Titre is the volume added. At least **two concordant titres** should be identified. These are titres within 0.20 cm³ (or sometimes 0.10 cm³) of each other. Calculate the mean titre.

Cells contain chemicals which react to produce electricity. The voltage produced by a cell is dependent upon a number of factors including the type of electrode and electrolyte.
Batteries consist of two or more cells connected together in series to provide a greater voltage.

In **non-rechargeable** cells and batteries the chemical reactions stop when one of the **reactants has been used up**. Alkaline batteries are non-rechargeable.

Rechargeable cells and batteries can be recharged because the **chemical reactions are reversed** when an external electrical current is supplied. The biggest voltage occurs when the difference in the reactivity of the two metals is the largest.

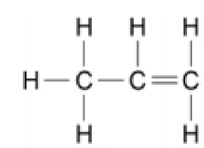
Fuel cells are supplied by an external source of fuel (eg hydrogen) and oxygen or air.
The fuel is **oxidised electrochemically** within the fuel cell to produce a potential difference. Energy is released as electrical energy, not **thermal energy**

The overall reaction in a **hydrogen fuel cell** involves the **oxidation of hydrogen to produce water**.
Hydrogen fuel cells offer a potential alternative to rechargeable cells and batteries.

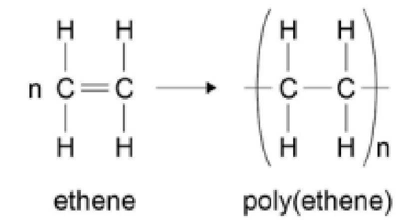
At the negative electrode: $2H_2 + 4OH^- \rightarrow 4H_2O + 4e^-$
At the positive electrode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$
$2H_2 + 4OH^- + O_2 + 2H_2O + 4e^- \rightarrow 4H_2O + 4e^- + 4OH^-$
The hydroxide ions, electrons and two H_2O molecules will now cancel because they are on both sides, leaving the overall equation:
$2H_2 + O_2 \rightarrow 2H_2O$

C2+

Alkenes are hydrocarbons with a double **carbon-carbon bond** C=C. Cn H2n
Alkene molecules are **unsaturated** because they contain two **fewer hydrogen atoms** than the alkane with the same number of carbon atoms.
The first four members of the **homologous series** of alkenes are **ethene, propene, butene and pentene**.



Alkenes can be used to make **polymers** such as poly(ethene) and poly(propene) by **addition polymerisation**. In addition polymerisation reactions, many small molecules (monomers) join together to form very large molecules (polymers).



Condensation polymerisation involves monomers with two functional groups. When these types of monomers react they join together, usually losing small molecules such as water

Alkenes react with **oxygen** in combustion reactions in the same way as other hydrocarbons, but they tend to burn in air with **smoky flames** because of **incomplete combustion**.
Alkenes react with **hydrogen, water and the halogens**, by the addition of atoms across the carbon-carbon double bond so that the double bond becomes a single carbon-carbon bond
Alkene + hydrogen → alkane (hydrogenation), Alkene + water (steam) → alcohol, Ethene + chlorine → dichloroethane

Alcohols contain the functional group **–OH**. **Methanol, ethanol, propanol and butanol** are the first four members of a homologous series
ethanol + oxygen → carbon dioxide + water, sodium + ethanol → sodium ethoxide + hydrogen

Alcohols with the shortest hydrocarbon chains are added to water, they mix easily to produce a solution. However, the **solubility** decreases as the length of the alcohol molecule gets longer. It may not mix easily, and two distinct layers might be left in the container.

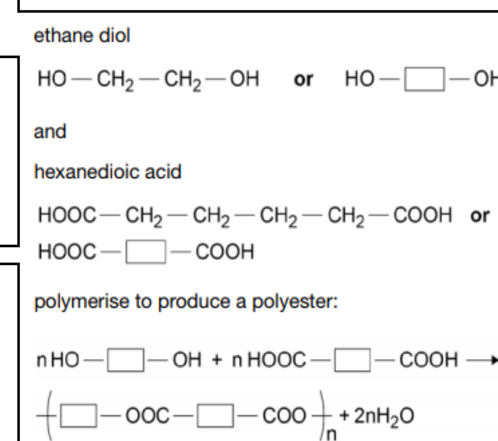
The alcohols can also be **oxidised** without **combustion** to produce **carboxylic acids**. For example, ethanol can be oxidised to ethanoic acid using an **oxidising agent**. **ethanol + oxidising agent → ethanoic acid + water**

Aqueous solutions of ethanol are produced when sugar solutions are **fermented** using yeast. Conditions required:
• an air lock to allow carbon dioxide out, while stopping air getting in
•warm **temperature**, 25-35°C

The yeast dies when the ethanol concentration reaches about 15%. Fermentation is a slow reaction and takes several days or weeks to finish. If air is present, the oxygen causes the ethanol to oxidise to ethanoic acid, so the drink tastes of vinegar.

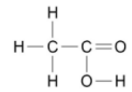
Amino acids have two different functional groups in a molecule. Amino acids react by condensation polymerisation to produce polypeptides

DNA (deoxyribonucleic acid) encodes genetic instructions for the development and functioning of living organisms and viruses. Most DNA molecules are two polymer chains, made from four different monomers called **nucleotides**, in the form of a double helix.



Glucose is the monomer of starch and cellulose

Carboxylic acids have the functional group –COOH. The first four members of a homologous series of carboxylic acids are **methanoic acid, ethanoic acid, propanoic acid and butanoic acid.**



The carboxylic acids have typical acid properties:
•**dissolve** in water to form **acidic solutions** with **pH** values less than 7
•react with **metals** to form a **salt** and hydrogen and react with **bases** to form a salt and water
•react with carbonates to form a salt, water and carbon dioxide

Carboxylic acids can react with **alcohols** to make **esters**. Esters are **organic compounds** which all contain the **functional group** -COO-. Esters have fruity smells and can be used as **solvents**.
alcohol + carboxylic acid → ester + water

Carboxylic acids are weak acids. This means that their solutions do not contain many hydrogen ions compared with a solution of a strong acid with the same **concentration**. The pH of a weak acid will be higher than the pH of a strong acid, if their concentrations are the same.In a solution of a strong acid, the molecules are fully ionised, but in a weak acid, very few of the molecules are **ionised**

Flame tests can be used to identify some metal ions (cations). If a sample containing a mixture of ions is used some flame colours can be masked.

Element	Flame Colour
Lithium	Crimson
Sodium	Yellow
Potassium	Lilac
Calcium	Orange-red
Copper	Green

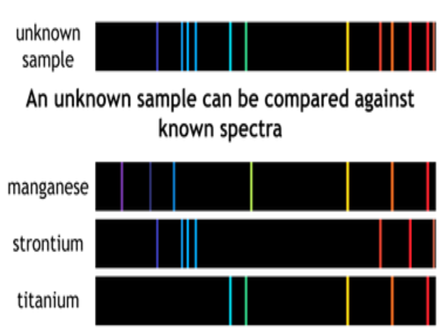
Element	Precipitate with sodium hydroxide solution
Calcium	White
Magnesium	White
Aluminium	White. Will dissolve in excess solution
Copper (II)	Blue
Iron (II)	Green
Iron (III)	Brown

Carbonates react with dilute acids to form carbon dioxide gas. Carbon dioxide can be identified with limewater.

Halide ions in solution produce precipitates with silver nitrate solution in the presence of dilute nitric acid. **Silver chloride is white, silver bromide is cream and silver iodide is yellow.**

Sulfate ions in solution produce a white precipitate with barium chloride solution in the presence of dilute hydrochloric acid.
RP: Use of chemical tests to identify the ions in unknown single ionic compounds covering the ions

Instrumental methods are accurate, sensitive and rapid.
Flame emission spectroscopy is used to analyse metal ions in solutions. The sample is put into a flame and the light given out is passed through a spectroscope. The output is a line spectrum that can be analysed to identify the metal ions in the solution and measure their concentrations.



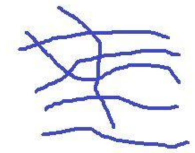
Bronze is an alloy of copper and tin. **Brass** is an alloy of copper and zinc. **Gold** used as jewellery is usually an alloy with silver, copper and zinc. The proportion of gold in the alloy is measured in carats. 24 carat being 100% (pure gold), and 18 carat being 75% gold.

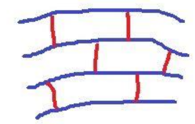
Steels are alloys of iron that contain specific amounts of carbon and other metals.
High carbon steel is strong but brittle.
Low carbon steel is softer and more easily shaped. Steels containing chromium and nickel (stainless steels) are hard and resistant to corrosion. **Aluminium alloys** are low density.

Corrosion is the destruction of materials by chemical reactions with substances in the environment. **Rusting** is an example of corrosion. Both air and water are necessary for iron to rust.
Corrosion can be prevented by applying a coating that acts as a barrier, such as **greasing, painting or electroplating**. Aluminium has an oxide coating that protects the metal from further corrosion. Some coatings are reactive and contain a more reactive metal to provide sacrificial protection, eg zinc is used to galvanise iron.

Most of the **glass** we use is **soda-lime glass**, made by heating a mixture of sand, sodium carbonate and limestone. **Borosilicate glass,** made from sand and boron trioxide, melts at higher temperatures than soda-lime glass.
Clay ceramics, including pottery and bricks, are made by shaping wet clay and then heating in a furnace.

The properties of **polymers** depend on what monomers they are made from and the conditions under which they are made. Low density (LD) and high density (HD) poly(ethene) are produced from ethene.
Thermosoftening polymers melt when they are heated. **Thermosetting polymers** do not melt when they are heated.


Thermosoftening


Thermosetting

Most **composites** are made of two materials, a matrix or binder surrounding and binding together fibres or fragments of the other material, which is called the reinforcement e.g. Reinforced concrete, is made of steel and concrete. Fibre glass is made of glass fibres and polymer resin.

Ammonia is an important industrial product used to make **fertilisers**, explosives and dyes. It is manufactured using the **Haber process**. This involves a **reversible reaction** between nitrogen and hydrogen:
$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ The reaction can reach a dynamic **equilibrium**
1.nitrogen (extracted from the air) and hydrogen (obtained from **natural gas**) are pumped through pipes
2.the **pressure** of the mixture of gases is increased to 200 **atmospheres**
3.the pressurised gases are heated to 450°C and passed through a tank containing an iron **catalyst**
4.the reaction mixture is cooled so that ammonia **liquefies** and can be removed
5.unreacted nitrogen and hydrogen are **recycled**

Compounds of **nitrogen, phosphorus and potassium** are used as NPK fertilisers to improve agricultural productivity. Industrial production of NPK fertilisers can be achieved using a variety of raw materials in several integrated processes.

Fertiliser compounds must be **soluble** in water so they can be absorbed by the root hair cells:
•ammonium ions, NH_4^+, and nitrate ions, NO_3^-, are sources of soluble nitrogen
•phosphate ions, PO_4^{3-}, are a source of soluble phosphorus
•all common potassium compounds **dissolve** in water to produce potassium ions, K^+

NPK fertilisers are **formulations** of **various salts** containing appropriate percentages of the elements. **Ammonia** can be used to manufacture **ammonium salts and nitric acid**. Ammonia (NH_3) is an alkali and when it is involved in **neutralisation** reactions, it produces the ammonium ion (NH_4^+) which is present in lots of fertilisers.

Potassium chloride, potassium sulfate and phosphate rock are obtained by mining, but phosphate rock cannot be used directly as a fertiliser. Phosphate rock is treated with nitric acid or sulfuric acid to produce soluble salts that can be used as fertilisers.

P reacts with…	Compound(s) produced
Nitric acid	Calcium nitrate & phosphoric acid (which is neutralised with ammonia to make ammonium phosphate)
Sulfuric acid	Single superphosphate (a mixture of calcium sulfate and calcium phosphate)
Phosphoric acid	Triple superphosphate (calcium phosphate)

Factor	Industrial method	Laboratory method
Temperature	Different stages require temperatures between 60°C and 450°C	Room temp for neutralisation, then heating to evaporate the water
Equipment and process	Very expensive chemical plant machinery, used in a continuous process	Cheap and versatile laboratory equipment, used in a batch process
Starting materials	Reactants are made from raw materials, eg sulfur, air, water	Reactants are purchased from a chemical supplier
Scale/yield	Huge quantities can be made quickly.	Small quantities are made slowly