GCSE Chemistry (Modular) - Module 21 Revision Guide

The water cycle

Water is the most abundant substance on the surface of our planet and is essential for all life. In the water cycle, water in rivers, lakes and the oceans is evaporated by the heat of the Sun. The water vapour formed rises into the atmosphere and forms clouds. The clouds cool as they rise further and produce rain.

Water for drinking and for industry

Water is an important raw material and has many uses:

- it is used as a solvent and as a coolant (e.g. in power stations);
- it is used in many industrial processes, including the manufacture of sulphuric acid.

Drinking water is treated by passing water through filter beds to remove solid particles and then chlorine is added to kill bacteria. The use of artificial fertilisers results in many natural waters being contaminated with dissolved nitrate and ammonium ions. Dissolved nitrate ions can have harmful effects on babies and so the levels of nitrate are carefully monitored.

Hard and soft water

Soft water readily forms lather with soap. Many compounds dissolve in water and some of these make the water hard.

Most hard water contains dissolved calcium or magnesium compounds. The hard water is formed when natural waters flow over ground or rocks containing calcium or magnesium compounds. Hard water does not easily form lather with soap because these dissolved compounds react with soap to form scum.

Advantages of hard water	Disadvantages of hard water
Contains dissolved compounds that are good for health. Hard water often provides calcium compounds that help the development of strong bones and teeth and help to reduce heart illnesses.	Increased costs: • more soap is needed; • deposits (scale) in heating systems and kettles

Hard water can be made soft by removing the dissolved calcium and magnesium ions:

- by adding sodium carbonate solution to precipitates out calcium carbonate or magnesium carbonate;
- by ion exchange columns, which contain hydrogen ions or sodium ions – these replace calcium and magnesium ions when the hard water passes down the column.

How well do different gases dissolve in water?

Many gases are soluble in water, but some gases are more soluble than others and some are hardly soluble at all. The solubility of gases in water also depends on the temperature of the water.

Gases are more soluble at low temperatures and high pressures.

Carbonated water is produced by dissolving carbon dioxide under high pressure. When the pressure is released the gas bubbles out of the solution. Carbonated water is used in fizzy drinks.

Dissolved oxygen is essential for aquatic life. Hot water from power stations may be discharged into rivers or lakes, but this reduces the amount of oxygen dissolved in the water, so damaging aquatic life.

Chlorine water is made by dissolving chlorine gas in water. Chlorine water is used to bleach materials and kill bacteria.

How well do different solids dissolve in water?

Most ionic compounds (such as sodium chloride, copper sulphate) are soluble in water. Most covalent compounds (such as oxygen, copper oxide) are insoluble in water.

The solubility of most solutes increases as the temperature increases.
A saturated solution is one in which no more solute will dissolve at that temperature.
When a hot saturated solution cools some of the solute will separate from the solution.

The solubility of a solute in water, or any other solvent, is usually given in grams of solute per 100 grams of water (or solvent) at that temperature.

You should be able to:

- interpret solubility curves and use solubility curves to explain crystallisation.

Why do some substances produce acidic or alkaline solutions?

Some soluble substances produce acidic or alkaline solutions. This happens because these substances react in a special way with the water. Water must be present for a substance to act as an acid or as a base.

Acids	Bases
Produce H^+ (aq) ions (protons) in aqueous solution	Produce OH^- ions in aqueous solution
Proton donors	Proton acceptors
Strong acids are 100% ionised in water, e.g. • hydrochloric acid • sulphuric acid • nitric acid	Strong base are 100% ionised in water, e.g. • sodium hydroxide • potassium hydroxide
Weak acids are only partially ionised in water, e.g. • ethanoic acid • citric acid • carbonic acid	Weak alkalis are only partially ionised in water, e.g. ammonia solution

You should be able to:

- describe the contributions of Arrhenius, Lowry and Brønsted to our understanding of acids and bases;
- explain why the work of Arrhenius took longer to be accepted than Lowry's and Brønsted's work; and
- describe how to distinguish between strong and weak acids of the same concentration by using the pH scale or the rate of reaction with metals.

What different ways are there of making salts?

There are several general methods of producing salts:

- reaction of a metal with an acid;
- reaction of an insoluble base with an acid;
- reaction of a soluble base (alkali) with an acid;
- by mixing two solutions to form an insoluble salt (precipitation); and
- by direct combination of the elements to form anhydrous salts, e.g.

$$2Al + 3Cl_2 \rightarrow 2AlCl_3 \text{ and } 2Fe + 3Cl_2 \rightarrow 2FeCl_3$$

You should be able to give practical details of salt preparations based on each of these methods.

How can we work out the concentration of solutions?

It is very useful to know exactly how much of a dissolved substance is present in a certain volume of a solution, so we need a standard way of comparing the concentrations of solutions.

The relative atomic mass of an element (A_r) or the relative formula mass of a compound (M_r) in grams is equal to one mole of that substance.

You should be able to:

- calculate the number of moles of a substance using given formula and relative atomic or formula masses; and
- calculate the mass of a substance in a given mole quantity of that substance.

The concentration of a solution is expressed in terms of mole per cubic decimetre (mol dm^{-3}) (M).
You should be able to:

- calculate the number of moles or mass of substance in an aqueous solution of given volume and concentration;
- calculate the concentration of an aqueous solution given the amount of substance and volume of water.

Titrations

The volume of acid and alkali solutions which neutralise each other can be measured by titration using a suitable indicator. You should be able to describe how a titration is carried out.

Titrations can be used to find the concentration of an acid or alkali from the relative volumes used and the concentration of one of the two reactants. You should be able to carry out calculations involving neutralisation reactions in aqueous solution (the balanced equation will be given).

What is produced when organic compound are burned?

Some organic compounds are used as fuels. Other organic compounds, including plastics, are burned as waste. Burning these organic compounds releases gases into the atmosphere.

Coal, crude oil, natural gas and wood contain organic compounds. Organic compounds contain carbon. When organic compounds are burned in a plentiful supply of air:

- the carbon is oxidised to carbon dioxide; and
- the hydrogen is oxidised to water.

In a limited supply of air incomplete combustion occurs, forming carbon monoxide and/or carbon. Carbon monoxide is poisonous because it reduces the capacity of blood to carry oxygen.

You should be able to use given data to compare the:

- cost;
- efficiency; and
- cleanliness of burning different fossil fuels

Plastics (and other organic compounds) which contain chlorine and nitrogen produce poisonous fumes when burnt, especially where there is a limited supply of air. These are:

- hydrogen chloride from the chlorine; and
- hydrogen cyanide from the nitrogen

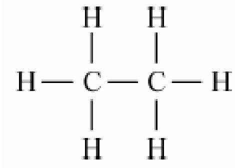
The combustion products of carbon (carbon dioxide) and hydrogen (water) are also formed.

Families of organic compounds

Organic compounds belong to different families, called homologous series.
The compounds in each homologous series have:

- a similar chemical structure; and
- a similar chemical formula.

Alkanes

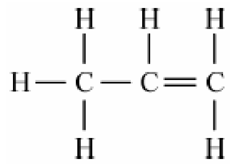


The saturated hydrocarbons form a homologous series called alkanes with a general formula C_nH_{2n+2}. You should be able to represent and interpret alkane molecules as shown (for ethane) on the right:

Alkanes undergo combustion reactions, e.g. ethane + oxygen → carbon dioxide + water

$$C_2H_6(g) + 3\tfrac{1}{2}O_2 \rightarrow 2CO_2(g) + 3H_2O(g)$$

Alkenes



The unsaturated hydrocarbons form a homologous series called alkenes with a general formula C_nH_{2n}. You should be able to represent and interpret alkene molecules as shown (for propene) on the right:

Alkenes undergo combustion reactions, e.g. propene + oxygen → carbon dioxide + water

$$C_3H_6(g) + 4\tfrac{1}{2}O_2 \rightarrow 3CO_2(g) + 3H_2O(g)$$

Isomers

Isomerism occurs when two or more compounds have the same chemical formula but have different structures. You should be able to:

- draw the isomers of butane and pentane; and
- show an understanding of isomerism by predicting some of the structures of the isomers of given higher alkanes, e.g. hexane

Isomers have different physical properties which depend upon the strength of the intermolecular forces. The strength of intermolecular forces increases as:

- the carbon chain length increases; and
- decreases as the amount of chain branching increases.

You should be able to predict and explain the differences in the boiling points of isomers of alkanes in terms of intermolecular forces arising from the ability of the molecules to pack closely. For example, hexane (with no branches) has a boiling point of 69ºC, 2-methylpentane (with one branch) has a boiling point of 60ºC and 2,2-dimethylbutane (with two branches) has a boiling point of just 50ºC.

The alkenes are more reactive than alkanes because of the presence of the C=C double bond. The alkenes undergo addition reactions in which one of the bonds in the C=C double bond breaks: this allows each carbon atom to form a covalent bond with another atom. Examples of addition reactions are:

- with hydrogen in the presence of a catalyst to form alkanes;
- with bromine when alkenes decolourise bromine water.

Vegetable oils contain unsaturated fats and can be hardened to form margarine by adding hydrogen on to some of the C=C double bonds.

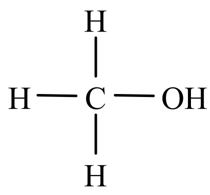
Alcohols

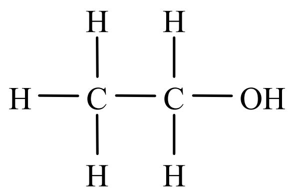
The alcohols are members of a homologous series with the functional group −OH, called the hydroxyl group. This functional group gives alcohols their characteristic properties:

- they react with sodium to form hydrogen;
- they react, reversibly, with carboxylic acids to form esters and water.

The steroid, cholesterol, also contains the alcohol group –OH. Cholesterol is an essential steroid to humans but if too much is produced it can cause heart disease.

You should be able to draw the structures of methanol and ethanol:





What is ethanol?

What we call alcohol in everyday life is a substance whose chemical name is ethanol: it is just one member of the alcohols homologous series. Ethanol, C_2H_5OH, is:

- used as a solvent;
- used as a fuel; and
- present in alcoholic drinks.

Ethanol can be oxidised to form ethanoic acid. It is this oxidation of ethanol that results in alcoholic drinks turning sour. Ethanol can be produced by fermenting sugars and by reacting ethene with steam.

Fermentation

Fermentation is a batch process.
The raw materials are mixed with water and yeast at just above room temperature. The yeast contains enzymes which are biological catalysts. The sugars react to form ethanol and carbon dioxide. The carbon dioxide is allowed to escape and air is prevented from entering the reaction vessel. When the reaction is over the ethanol is separated from the reaction mixture by fractional distillation.

Hydration of ethene

Hydration of ethene is a continuous process.
Ethanol can be produced by the reaction of steam and ethene in the presence of a strong acid catalyst (phosphoric acid). The reaction is carried out at a moderately high temperature and a high pressure.

Batch Process v Continous Process

	Fermentation	**Hydration of ethene**
Type of process	Batch	Continuous
Rate of reaction	Slow	Fast
Quality of product	Low (needs filtering and distilling)	High (ethanol is the only product formed)
Use of finite resources	Renewable sources used, e.g. sugar from sugar cane	Non-renewable sources used, e.g. ethene comes from cracking crude oil
Conditions of reaction	Just above room temperature Atmospheric pressure	Moderately high temperature High pressure
Catalyst	Enzymes in yeast	Phosphoric acid
Equation	$C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$	$C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(g)$

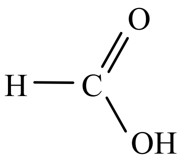
Carboxylic acids

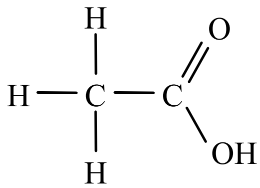
The acids that we find in fruits and in vinegar belong to a homologous series called carboxylic acids. Carboxylic acids form a homologous series and have the functional group −COOH. These are examples:

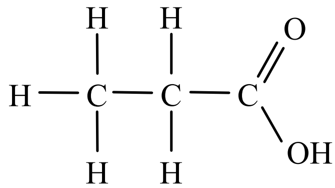
- ascorbic acid (vitamin C) – found in fresh fruit and vegetables.
- aspirin – a drug used for pain relief and taken regularly by those at risk from heart attacks; and
- citric acid – found in oranges, lemons and many soft drinks;
- ethanoic acid – found in vinegar and used in the manufacture of acetate rayon (an artificial fibre);

Carboxylic acids are weak acids. They are neutralised by alkalis and they react with carbonates and hydrogencarbonates to produce carboxylic acid salts, carbon dioxide and water.

You should be able to draw the structures of methanoic acid, ethanoic acid and propanoic acid:







Carboxylic acids react, reversibly, with alcohols to form esters. Concentrated sulphuric acid is used as a catalyst for this reaction. For example, methanol + ethanoic acid → methyl ethanoate + water

Esters

Esters are widely used as fragrances and food flavourings.

Polymers

Polymers do not form a homologous series, but they are all organic compounds with very long molecules. Most polymers are made from compounds containing the C=C bond by addition polymerisation, e.g.

- poly(ethene) is made from ethene;
- poly(propene) is made from propene; and
- poly(chloroethene) is made from chloroethene, CH_2=CHCl (but the polymer is usually called polyvinylchloride or PVC).

Polymers (plastics) consist of a tangled mass of very long molecules in which the atoms are joined by strong covalent bonds to form long chains. There are two main types of polymer:

Type of plastic	Thermosoftening plastics	Thermosetting plastics
Forces between polymer chains	Weak forces	Strong covalent bonds (cross-links) that form when the plastic is first heated
Properties	Plastic softens when heated and hardens again when cooled	Cannot be softened and re-moulded
Examples	Poly(ethene) – also called polythene Poly(propene) – also called polypropylene PVC	Melamine (used in furniture) Many glues

Remember:

Don’t leave your revision until the last minute!