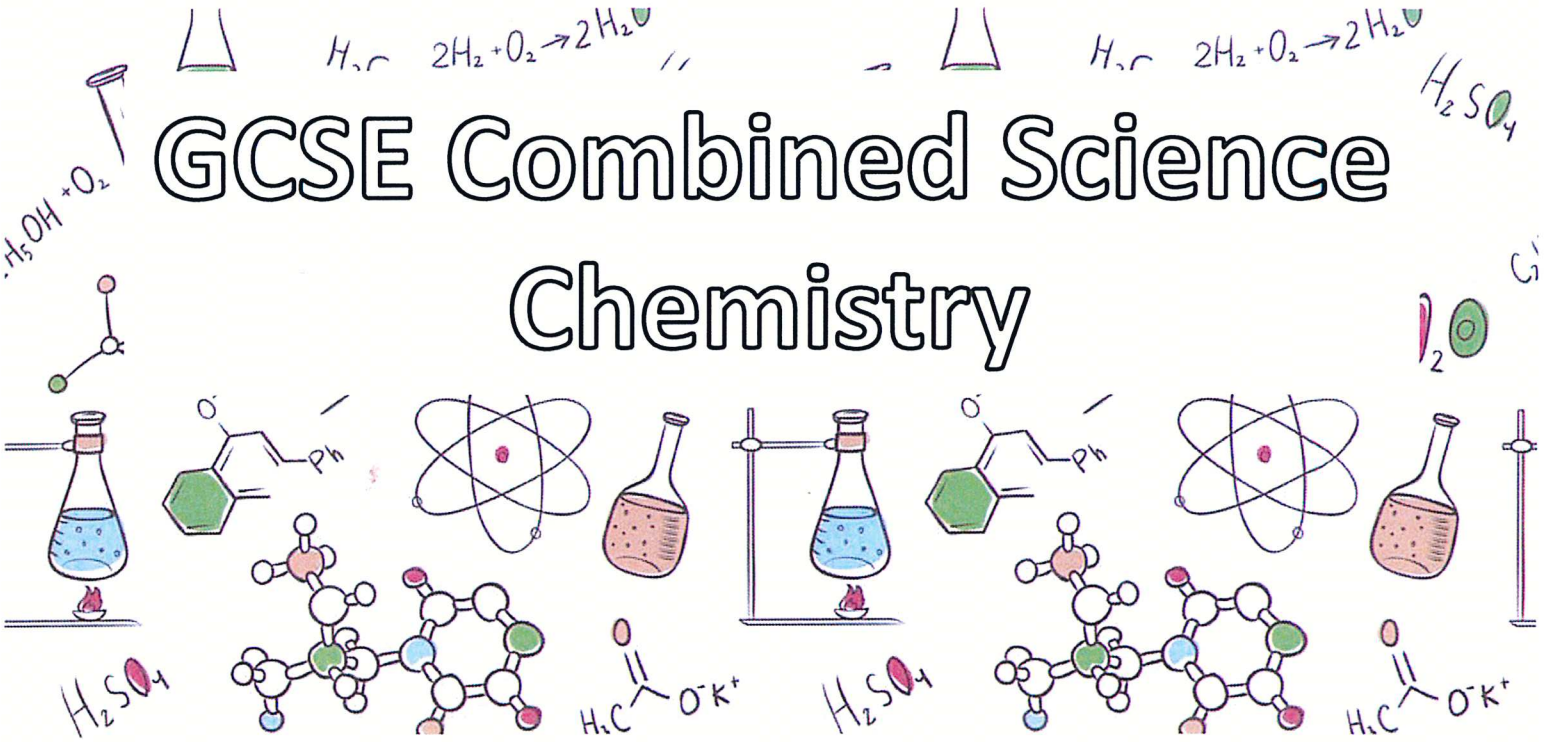
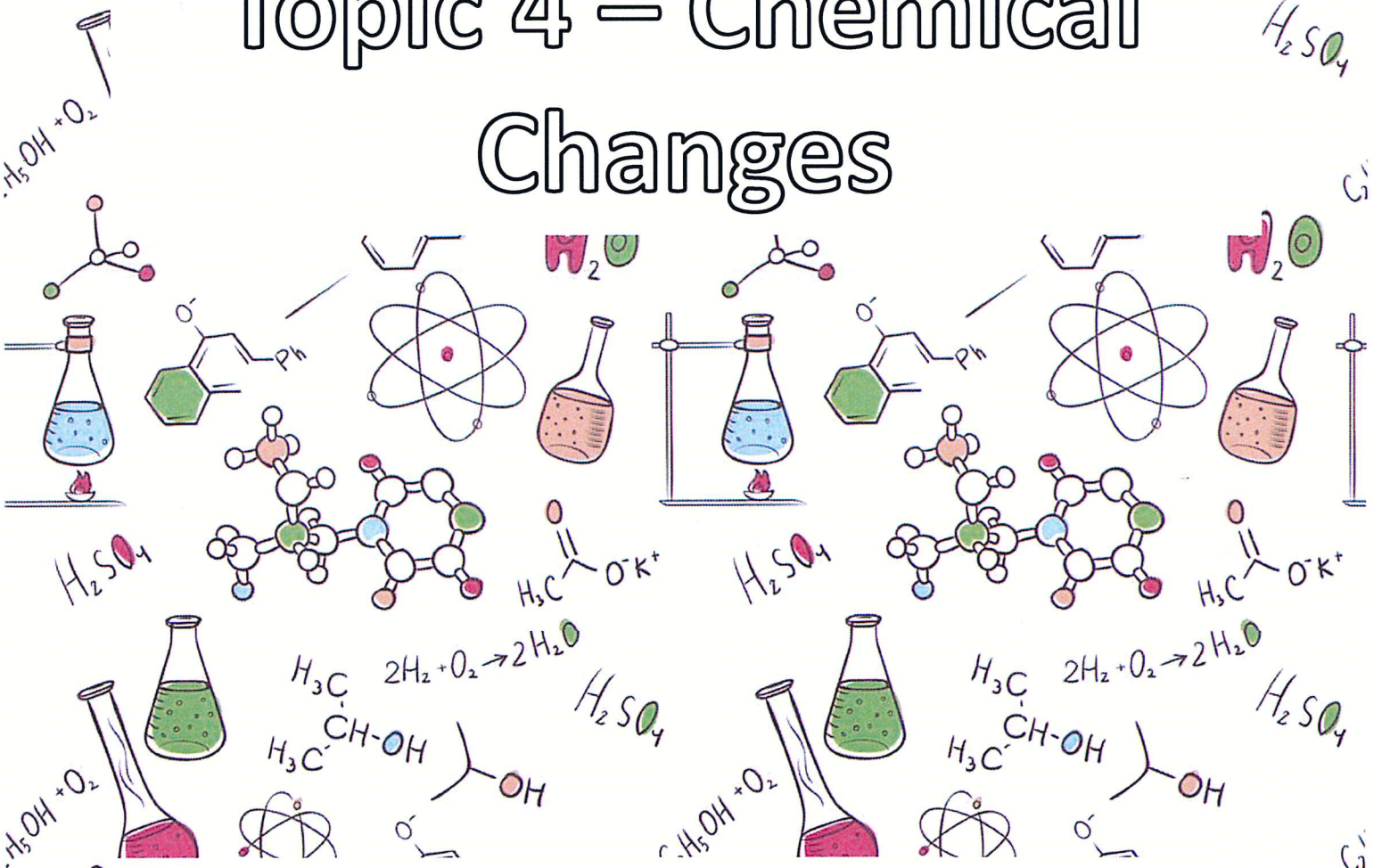
GCSE Combined Science

Chemistry



Topic 4 – Chemical Changes



Name: _____

C3 Chemical Changes

Can you...?	☺	😐	☹
4.1.1 Metal oxides			
Recall that metals react with oxygen to produce metal oxides.			
Describe reduction and oxidation in terms of loss or gain of oxygen.			
4.1.2 The reactivity series			
Explain what determines the reactivity of a metal.			
Explain why displacement reactions occur.			
State and describe the reactions, if any, of potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper with water.			
State and describe the reactions, if any, of potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper with dilute acids			
Place these metals in order of reactivity.			
Deduce an order of reactivity of metals based on experimental results.			
4.1.3 Extraction of metals and reduction			
Explain why some metals such as gold are found in the Earth as the metal itself but most metals are found as compounds that require chemical reactions to extract the metal.			
State what determines whether a metal can be extracted from its oxide by reduction carbon.			
Interpret or evaluate specific metal extraction processes when given appropriate information			
Identify the substances which are oxidised or reduced in terms of gain or loss of oxygen.			
4.1.4 Oxidation and reduction in terms of electrons (HT only)			
Describe reduction and oxidation in terms of loss or gain of electrons.			
Write ionic equations for displacement reactions.			
Identify in a given reaction, symbol equation or half equation which species are oxidised and which are reduced.			
4.2.1 Reactions of acids with metals			
Recall that acids react with some metal to produce salts and hydrogen.			
Explain in terms of gain or loss of electrons, that these are redox reactions.			
Identify which species are oxidised and which are reduced in given chemical equations.			
4.2.2 Neutralisation of acids and salt production			
Recall that acids are neutralised by alkalis (eg soluble metal hydroxides) and bases (eg insoluble metal hydroxides and metal oxides) to produce salts and water.			

C3 Chemical Changes

Can you...?	☺	😐	☹
Recall that Acids are neutralised by metal carbonates to produce salts, water and carbon dioxide.			
Name salts produced by these reactions.			
Predict products from given reactants.			
Use the formulae of common ions to deduce the formulae of salts.			
4.2.3 Soluble salts			
State the reactions that can be used to make soluble salts.			
Describe how to make pure, dry samples of named soluble salts from information provided.			
4.2.4 The pH scale and neutralisation			
Recall that acids produce hydrogen ions (H^+) in aqueous solutions.			
Recall that aqueous solutions of alkalis contain hydroxide ions (OH^-).			
Describe what the pH scale is and how it is used.			
Recall that in neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water.			
State the ionic equation for a neutralisation reaction.			
Describe the use of universal indicator or a wide range indicator to measure the approximate pH of a solution.			
Use the pH scale to identify acidic or alkaline solutions.			
4.2.5 Titrations (Chemistry only)			
Recall that the volumes of acid and alkali solutions that react with each other can be measured by titration using a suitable indicator.			
Describe how to carry out titrations using strong acids and strong alkalis only (sulfuric, hydrochloric and nitric acids only) to find the reacting volumes accurately			
Calculate the chemical quantities in titrations involving concentrations in mol/dm^3 and in g/dm^3. (HT Only)			
4.2.6 Strong and weak acids (HT only)			
State what a strong acid is and give examples.			
State what a weak acid is and give examples.			
Recall that for a given concentration of aqueous solutions, the stronger an acid, the lower the pH.			
Recall that as the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10.			
Use and explain the terms dilute and concentrated, and weak and strong in relation to acids			

C3 Chemical Changes

Can you...?	☺	😐	☹
Describe neutrality and relative acidity in terms of the effect on hydrogen ion concentration and the numerical value of pH (whole numbers only).			
4.3.1 The process of electrolysis			
State what happens to the ions in an ionic compound when it is melted or dissolved in water.			
State what an electrolyte is.			
Describe and explain what happens to ions during electrolysis.			
4.3.2 Electrolysis of molten ionic compounds			
Describe and explain what happens during the electrolysis of molten compounds..			
Predict the products of the electrolysis of ionic compounds in the molten state.			
4.3.3 Using electrolysis to extract metals			
Explain why electrolysis is used to extract some metals.			
Recall that large amounts of energy are used in the extraction process to melt the compounds and to produce the electrical current.			
Describe how aluminium is extracted using electrolysis.			
Explain why a mixture is used as the electrolyte during the extraction of aluminium.			
Explain why the positive electrode must be continually replaced during the extraction of aluminium.			
4.3.4 Electrolysis of aqueous solutions			
Recall that the ions discharged when an aqueous solution is electrolysed using inert electrodes depend on the relative reactivity of the elements involved.			
Explain what will be produced at the negative electrode (cathode) and how this is linked to the break down of water molecules.			
Explain what will be produced at the positive electrode (anode) and how this is linked to the break down of water molecules.			
Predict the products of the electrolysis of aqueous solutions containing a single ionic compound.			
4.3.5 Representation of reactions at electrodes as half equations (HT only)			
Describe and explain what happens are the cathode (negative electrode) and anode (positive electrode) in terms of electrons, oxidation and reduction.			
Write half equations for the reactions occurring at the electrodes.			

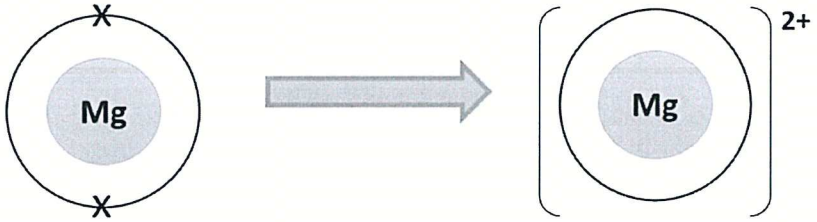
Topic 4 - Chemical changes

Understanding of chemical changes began when people began experimenting with chemical reactions in a systematic way and organizing their results logically. Knowing about these different chemical changes meant that scientists could begin to predict exactly what new substances would be formed and use this knowledge to develop a wide range of different materials and processes. It also helped biochemists to understand the complex reactions that take place in living organisms. The extraction of important resources from the earth makes use of the way that some elements and compounds react with each other and how easily they can be 'pulled apart'.

Reactions of metals

Reactivity is the tendency of a substance to take part in chemical reactions, either by itself or with other materials, to release energy.

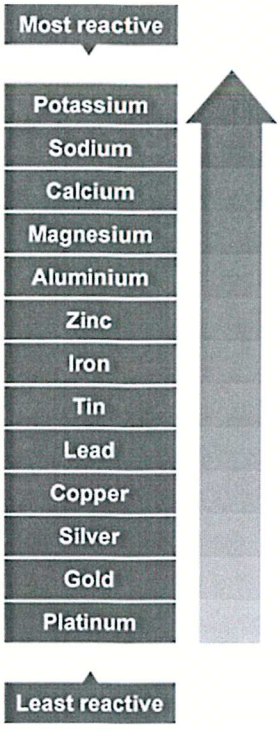
When metals react they lose electrons to become positively charged ions.



Metals are more reactive if they are more likely to form their positive ion.

The reactivity series

Metals can be arranged in order of their reactivity in a reactivity series. The metals potassium, sodium, lithium, calcium, magnesium, zinc, iron and copper can be put in order of their reactivity from their reactions with water and dilute acids.
The non-metals hydrogen and carbon are often included in the reactivity series. A more reactive metal can displace a less reactive metal from a compound.



Displacement reactions

A displacement reaction is a chemical reaction where a more reactive metal displaces a less reactive metal from its compound.

We can use the reactivity series to predict if a reaction will take place between a metal and a metal salt (metal containing compound).

E.g. copper sulphate + iron → iron sulphate + copper

Extraction of metals and reduction

Unreactive metals such as gold are found in the Earth as the metal itself but most metals are found as compounds that require chemical reactions to extract the metal.

1. What are the products of the reaction of potassium with water?

Tick **two** boxes.

- ☐ potassium chloride
- ☐ potassium hydroxide
- ☐ water
- ☐ hydrogen

[2 marks]

2. Complete the word equation for the reaction of a metal with sulfuric acid.

_____ + sulfuric acid → magnesium sulfate + _____ [2 marks]

3. A student adds small pieces of metal to water and dilute hydrochloric acid.

Their observations are shown in the table below:

Metal	Reaction with water	Reaction with dilute acid
A	Vigorous fizzing	Very vigorous fizzing
B	Nothing happens	Nothing happens
C	Nothing happens	Vigorous fizzing
D	Nothing happens	Small amount of fizzing

Remember
Less reactive metals do not react with water.

a Put the metals in order of reactivity, the most reactive first.

_____ [2 marks]

b Suggest which metal is copper.

Give a reason for your choice.

_____

_____ [2 marks]

Practical **c** Explain why the student is not allowed to carry out these tests using sodium. [2 mark]

Worked Example

To answer this question, consider what you know about sodium and how it reacts.

It is very reactive. [1 mark]

so it would not be safe [1 mark]

Marks gained: [2 marks]

Reactivity series – displacement

Figure 1 shows the reactivity series of metals.

Figure 1

1. Which metal listed in **Figure 1** can be used to displace zinc from zinc sulfate?

Tick **one** box.

☐ Iron ☐ Copper ☐ Magnesium ☐ Gold [1 mark]

2. Complete the displacement reaction word equations using metals from **Figure 1**.

Worked Example

a _____ + sodium → sodium carbonate + _____

[2 marks]

magnesium carbonate + sodium → sodium carbonate + *magnesium*

Marks gained: [2 marks]

b copper nitrate + _____ → iron nitrate + _____ [2 marks]

3. Study the equations for displacement reactions:

nickel chloride + cobalt → cobalt chloride + nickel

cobalt sulfate + chromium → chromium sulfate + cobalt

Put the metals nickel, cobalt and chromium in order of reactivity, the most reactive first.

Explain how you made your decision.

_____

_____ [3 marks]

Use the reactivity series in **Figure 3** to answer questions 1–2.

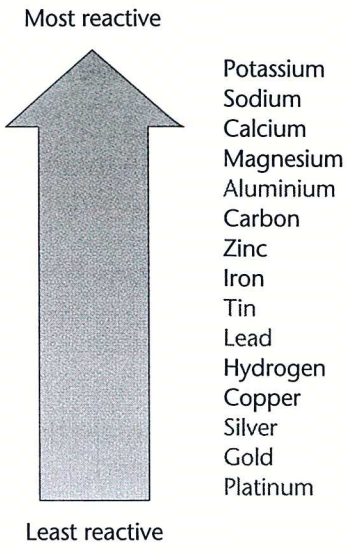


Figure 3

1. How is calcium found in the Earth?

Tick **one** box.

- ☐ As a mixture, with other metals
- ☐ As a mixture, with other elements
- ☐ In a compound, with other elements
- ☐ As a pure element

[1 mark]

2. Most metals are extracted from compounds using chemical reactions.

Draw **one** line from each metal to the method of its extraction.

Metal	Method of extraction
Iron	
aluminium	reduction with carbon
sodium	electrolysis
lead	

[4 marks]

Remember
Only metals less reactive than carbon can be extracted using reduction with carbon.

3. Zinc is extracted from zinc oxide.

The equation for the reaction is:

zinc oxide + carbon → zinc + carbon dioxide.

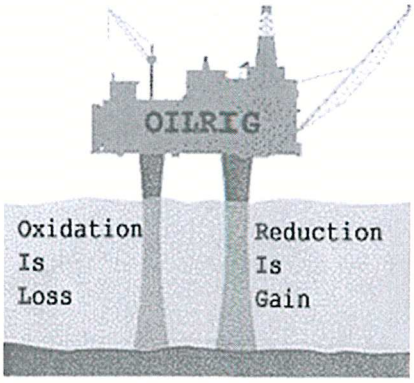
a Name the substance that is reduced _____ [1 mark]

b Name the substance that is oxidised _____ [1 mark]

Metals less reactive than carbon can be extracted from their oxides by reduction with carbon. Reduction involves the loss of oxygen.
If the metal is more reactive than carbon it requires electrolysis to separate the metal from its compound.

Oxidation and reduction in terms of electrons (HT only)

When a substance gains electrons in a chemical reaction it has been oxidised. If a substance has gained electrons during a chemical reaction it has been reduced.
Oxidation is the loss of electrons and reduction is the gain of electrons. (OILRIG)



Metal oxides

Metals react with oxygen to produce metal oxides. The reactions are oxidation reactions because the metals gain oxygen. Reduction and oxidation can be described in terms of loss or gain of oxygen.

The general equation for this type of reaction is:

Metal + oxygen → metal oxide

E.g. copper + oxygen → copper oxide

Metal hydroxides

Metals react with water to produce a metal hydroxide and hydrogen gas.

Metal + water → metal hydroxide + hydrogen

E.g. sodium + water → sodium hydroxide + hydrogen

Reactions of acids with metals

Acids react with some metals to produce metals salts and hydrogen.

Metal + acid → metal salt + hydrogen

Acids, alkalis and the pH scale

Acids are chemicals that release hydrogen ions (H^+) into a solution when added to water. It is these H^+ ions that make the chemicals acidic. Acids have a pH of less than 7. In universal indicator they go from red – orange – yellow.

Examples of acids include: stomach acid, lemon juice and vinegar.

Metal oxides

1. Which reactions are examples of oxidation?

Tick **two** boxes.

- ☐ sodium carbonate → sodium oxide + carbon dioxide
- ☐ magnesium + oxygen → magnesium oxide
- ☐ mercury oxide → mercury + oxygen
- ☐ zinc + oxygen → zinc(II) oxide

[2 marks]

2. Use the words in the box to complete the sentences.

carbonates	oxides	oxidation	reduction	oxates

Metals react with oxygen to produce metal _____.

This reaction is called _____. [2 marks]

3. A student tightly folds a sheet of copper in half.

They heat the copper using a Bunsen burner.

The outside of the copper turns black.

a Complete the word equation for the reaction

Copper + oxygen → _____ [1 mark]

Synoptic **b** Balance the symbol equation for the reaction.

$Cu + O_2 \rightarrow CuO$ [2 marks]

c The student leaves the copper to cool and then unfolds it.

The inside is not black.

Explain why.

_____

_____ [2 marks]

Synoptic

c Describe one environmental consequence associated with extracting zinc in this way.

_____

_____

_____ [2 marks]

Command word
You are asked to describe an issue. This means that you will need to discuss the consequence, rather than just name it.

Oxidation and reduction in terms of electrons

1. Which correctly describes what happens during oxidation?

Higher Tier only

Tick **one** box.

- ☐ A metal gains electrons to form ions.
- ☐ A metal loses electrons to form ions.
- ☐ A non-metal gains electrons to form ions.
- ☐ A non-metal loses electrons to form ions.

[1 mark]

Remember
OILRIG:
Oxidation **I**s electron **L**oss
Reduction **I**s electron **G**ain

2. Draw **one** line to the type of electron transfer.

Higher Tier only

Half equation	Type of electron transfer
$Na^+ + e^- \rightarrow Na$	
$2Cl^- \rightarrow 2e^- + Cl_2$	Oxidation
$Zn - 2e^- \rightarrow Zn^{2+}$	Reduction
$2F^- - 2e^- \rightarrow F_2$	

[4 marks]

Remember
The half equation
Mg – 2e⁻ → Mg can also be written as **Mg → Mg²⁺ + 2e⁻**

3. Balance the half equation:

Higher Tier only

$2O^{2-} \rightarrow$ _____ $e^- + O_2$ [1 mark]

4. Copper can be extracted from copper oxide by this reaction:

Higher Tier only

Copper oxide + carbon → copper + carbon dioxide

Synoptic

a Complete the balanced symbol equation for this reaction

_____CuO + _____ → 2Cu + _____ [3 marks]

b Which half equation correctly shows reduction in this reaction?

Tick **one** box.

☐ $C^{4-} + 4e^- \rightarrow C$ ☐ $2O^{2-} - 4e^- \rightarrow O_2$

☐ $2Cu^{2+} + 2e^- \rightarrow Cu$ ☐ $Cu \rightarrow Cu^{2+} + 2e^-$ [1 mark]

Reactions of acids with metals

1. Salts can be produced by reacting a metal with an acid.

State the acid and metal you would use to make the salt zinc(II) sulfate.

Metal _____

Acid _____ [2 marks]

2. A student adds magnesium strips to a beaker of hydrochloric acid.

a Complete the word equation for the reaction.

magnesium + hydrochloric acid → _____ + hydrogen [1 mark]

Worked Example

b Describe **one** sign that the magnesium is reacting with the acid [1 mark]

There are three signs to choose from:

Bubbles/fizzing from the hydrogen gas that is produced.

Temperature rise because this reaction is exothermic.

The magnesium gets smaller as it reacts to form magnesium chloride, which dissolves to form a solution.

Marks gained: [1 mark]

Alkalis are chemicals that form hydroxide ions (OH^-) when added to water. It is these OH^- ions that make the chemicals alkaline. Alkalis have a pH of greater than 7. In universal indicator they go from dark green – blue – purple.

Examples of alkalis include: soap, baking soda and oven cleaner.

The pH scale measures how strongly acidic or alkaline the substance is. The colour it turns in universal indicator is compared to a colour chart which gives a pH number for each colour. This pH number can tell us how concentrated the H^+ / OH^- ions are in the solution. A pH probe is an electronic device that can also measure the pH, the advantage of using this over universal indicator is that pH can be recorded over time, it is more accurate and it can be linked to a computer.

Neutralisation reactions

A neutralisation reaction is a chemical reaction that occurs between an acid and an alkali. The products are a neutral metal salt and water.

Acid + Alkali ⟶ Metal + Water
Salt

In neutralisation reactions between an acid and an alkali, hydrogen ions react with hydroxide ions to produce water. This reaction can be represented by the equation:

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

Naming metal salts

A metal salt the general name for a compound containing a metal that has been formed when a metal, wholly or partially, replaces the hydrogen in an acid.

To name a metal salt, the first part of its name come from the metal in the alkali/base and the second part comes from the type of acid used:

From alkali
E.g. **sodium** hydroxide

From acid:
Hydrochloric acid = chloride
Sulphuric acid = sulphate
Nitric acid = nitrate

Bases

Bases are substances that react with acids and neutralise them. They are usually metal oxides, metal hydroxides, metal carbonates or metal hydrogen carbonates.

Many bases are insoluble - they do not dissolve in water. If a base does dissolve in water, we call it an alkali.

A reaction between an acid and a base is still a neutralisation reaction so a metal salt and water are still produced, however depending on the base there may be other products. The rules for naming the metal salts are still the same.

Acids and metal oxides/hydroxides

An acid will react with a metal oxide/hydroxide to produce a metal salt and water.

Acid + metal oxide/hydroxide → metal salt + water

Acids and metal carbonates

An acid will react with a metal carbonate to produce a metal salt, water and carbon dioxide.

Acid + metal carbonate → metal salt + water + carbon dioxide

Soluble salts

Soluble salts can be made from acids by reacting them with solid insoluble substances, such as metals, metal oxides, hydroxides or carbonates. The solid is added to the acid until no more reacts and the excess solid are filtered off to produce a solution of the salt. Salt solutions can be crystallised to produce solid salts. *REQUIRED PRACTICAL*

Strong and weak acids (HT only)

All acids release hydrogen ions (H^+) when dissolved in water – that's what makes them acids! The readiness of an acid to ionise (release H^+ ions) in water determines the strength of the acid. The more H^+ ions an acid releases, the stronger the acid.

A strong acid is completely ionised in aqueous solution. Examples of strong acids are hydrochloric, nitric and sulphuric acids.

E.g. $HCl_{(aq)} \rightarrow H^+_{(aq)} + Cl^-_{(aq)}$

A weak acid is only partially ionised in aqueous solution. Examples of weak acids are ethanoic, citric and carbonic acids.

E.g. $CH_3COOH_{(aq)} \quad CH_3COO^-_{(aq)} + H^+_{(aq)}$

For a given concentration of aqueous solutions, the stronger an acid, the lower the pH. As the pH decreases by one unit, the hydrogen ion concentration of the solution increases by a factor of 10.

Synoptic **c** Describe the test the student can carry out to prove that hydrogen is made.

_____

_____ [3 marks]

d Use the information below to write the balanced symbol equation for this reaction

Magnesium ion = Mg^{2+}

Hydrochloric acid ions = H^+Cl^-

Analyse the question

The charges on the ions will help you to work out the formula of the compounds.

Magnesium chloride has the formula $MgCl_2$ because 1 magnesium ion needs to join to 2 chlorine atoms to balance out the charges.

_____ [4 marks]

Neutralisation of acids and making salts

1. Metal oxides are bases.

Which statements are correct about metal oxides?

Tick **two** boxes.

☐ They are soluble. ☐ They are insoluble.

☐ They neutralise alkalis. ☐ They neutralise acids. [2 marks]

2. Name the missing product in the word equation.

potassium hydroxide + hydrochloric acid → _____ + water

[1 mark]

Remember

The second part of the salt's name comes from the acid:

Hydrochloric acid makes chlorides.

Sulfuric acid makes sulfates.

Nitric acid makes nitrates.

3. Draw **one** line from the reactants of a neutralisation reaction to the products.

Worked Example

Reactants	Products
Calcium hydroxide + hydrochloric acid	Calcium sulfate + water + carbon dioxide
Calcium oxide + sulfuric acid	Calcium chloride + water
Calcium carbonate + sulfuric acid	Calcium sulfate + water
Calcium oxide + nitric acid	Calcium nitrate + water

[4 marks]

4. Name the acid and alkali used to produce the salt potassium nitrate.

Acid _____ Alkali _____ [2 marks]

Making soluble salts

1. A student is asked to prepare a pure, dry sample of a soluble salt.

The method they follow is:

A. Gently warm 100 cm^3 of sulfuric acid in a beaker using a Bunsen burner.

B. Add a spatula of copper oxide to the acid and stir.

C. Keep adding copper oxide until it is in excess.

D. Remove the excess copper oxide.

E. Crystallise the salt solution.

a State one hazard and way of reducing the risk of harm when carrying out step A.

Hazard: _____

Way of reducing the risk of harm: _____ [2 marks]

b Explain how the student will know when to stop adding copper oxide in step C.

_____ [1 mark]

c Name the salt that is produced.

_____ [1 mark]

d Draw a labelled diagram to show the equipment the student should use for step D.

[2 marks]

e Name this technique _____ [1 mark]

2. They use the equipment in **Figure 4** to carry out step E.

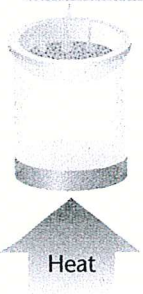


Figure 4

a Label the equipment in **Figure 4** to show the:

– Water bath

– Salt solution [2 marks]

b Describe how the technique will produce crystals of pure salt.

_____

_____

_____ [2 marks]

pH and neutralisation

1. Which ion do **all** acids contain?

Tick **one** box.

☐ Cl^- ☐ SO_4^{2-} ☐ H^+ ☐ OH^- [1 mark]

2. What can be used to measure pH?

Tick **two** boxes.

☐ Litmus solution ☐ A burette

☐ Universal indicator ☐ pH probe [2 marks]

3. Draw **one** line from the pH range to the type of solution.

pH range	Type of solution
1–6	Acidic
7	Alkaline
8–14	Neutral

[3 marks]

4. Complete the equation to show neutralisation.

H^+ (aq) + _____ (aq) → H_2O (_____) [2 marks]

5. A sodium chloride solution can be produced by adding hydrochloric acid to sodium hydroxide.

a Explain how you could use universal indicator to check when the reaction is **just** complete.

_____

_____

_____ [3 marks]

b State **one** disadvantage of using universal indicator for this technique.

_____

_____ [1 mark]

Titrations

Separate Sciences only

1. A titration is used to find the volume of acid that reacts with 25 cm^3 of alkali. **Figure 5** shows the equipment used.

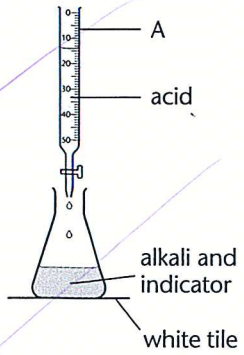


Figure 5

a What type of reaction takes place between an acid and alkali?

_____ [1 mark]

b Name the equipment labelled A.

Tick **one** box.

☐ Burette ☐ Measuring cylinder

☐ Meniscus ☐ Pipette [1 mark]

c Suggest the function of the white tile.

_____

_____ [2 marks]

d State the instrument that should be used to measure the volume of **alkali**.

Give a reason for your choice.

Instrument _____

Reason _____

_____ [2 marks]

2. The reacting volume of acid is measured four times.

Table 1 shows the results.

Volume of acid in cm^3			
1st trial	2nd trial	3rd trial	4th trial
25.8	26.4	29.5	26.2

a Draw a ring around the anomalous result. [1 mark]

Maths **b** Calculate the mean volume of acid using the remaining three volumes.

_____

_____

_____ [2 marks]

Maths
Remember to round your answer to the same number of significant figures as the numbers in the question. In this case, it is to 3 s.f.

Strong and weak acids

1. Draw a ring around the correct answer to complete each sentence.

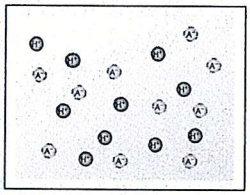
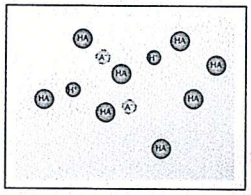
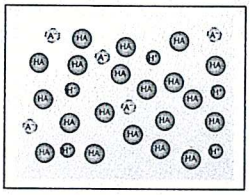
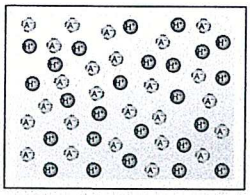
Higher Tier only

A strong acid [partially ionises / does not ionise / fully ionises] in aqueous solution to produce [H^+ ions / H^- ions / OH^- ions]

An example of a strong acid is [carbonic / citric / nitric] acid. [3 marks]

2. Draw **one** line from the particle diagram to the type of acid it represents.

Higher Tier only

Particle diagram	Type of acid
	Strong and dilute
	Weak and concentrated
	Strong and concentrated
	Weak and dilute

[4 marks]

3. The pH scale is related to the concentration of hydrogen ions.

Higher Tier only

Explain what happens to pH when the concentration of an acid increases.

_____

_____

[2 marks]

The process of electrolysis

1. **Figure 7** shows the equipment used to carry out electrolysis.

a Which letter is pointing to the **cathode**?

Tick **one** box.

A ☐ B ☐ C ☐ D ☐

[1 mark]