

# Chapter 5: Chemical changes 1

## Knowledge organiser

### Reactions of metals

The **reactivity** of a metal is how chemically reactive it is. When added to water, some metals react very vigorously – these metals have *high* reactivity. Other metals will barely react with water or acid, or won't react at all – these metals have *low* reactivity.

### Reactivity series

The reactivity series places metals in order of their reactivity. Sometimes, for example in the table below, hydrogen and carbon are included in the series, even though they are non-metals.

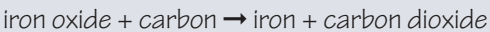
Reaction with water	Reaction with acid	Reactivity series		Extraction method
		Metal	Reactivity	
fizzes, gives off hydrogen gas	explodes	potassium	<div>high reactivity</div> <div>Decreasing reactivity</div> <div>low reactivity</div>	electrolysis
		sodium		
reacts very slowly	fizzes, gives off hydrogen gas	lithium		
		calcium		
		magnesium		reduction with carbon
		aluminium (carbon)		
no reaction	no reaction	zinc		
		iron		
		tin		mined from the Earth's crust
		lead (hydrogen)		
		copper		
		silver		
		gold		

### Metal extraction

Some metals, like gold, are so unreactive that they are found as pure metals in the Earth's crust and can be mined.

Most metals exist as compounds in rock and have to be extracted from the rock. If there is enough metal compound in the rock to be worth extracting it is called an **ore**.

Metals that are less reactive than carbon can be extracted by reduction with carbon. For example:



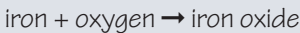
Metals that are more reactive than carbon can be extracted using a process called **electrolysis**.

### Reduction and oxidation

If a substance gains oxygen in a reaction, it has been **oxidised**.

If a substance loses oxygen in a reaction, it has been **reduced**.

For example:



iron has been oxidised

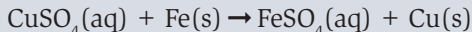


iron oxide has been reduced

### Displacement reactions

In a **displacement** reaction a *more* reactive element takes the place of a *less* reactive element in a compound.

For example:

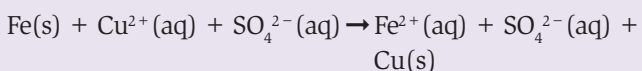


Iron is more reactive than copper, so iron displaces the copper in copper sulfate.

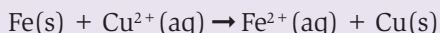
### Ionic equations (HT only)

When an ionic compound is dissolved in a solution, we can write the compound as its separate ions. For example,  $\text{CuSO}_4(\text{aq})$  can be written as  $\text{Cu}^{2+}(\text{aq})$  and  $\text{SO}_4^{2-}(\text{aq})$ .

The displacement reaction of copper sulfate and iron can be written as:



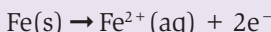
The  $\text{SO}_4^{2-}$  is unchanged in the reaction – it is a **spectator ion**. Spectator ions are removed from the equation to give an **ionic equation**:



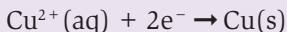
Metals, covalent substances, and solid ionic substances do not split into ions in the ionic equation.

### Half equations (HT only)

In the displacement reaction, an iron atom loses two electrons to form a iron ion:



A copper ion gains two electrons to form a copper atom:



These two equations are called **half equations** – they each show half of the ionic equation.

### Reactivity and ions

A metal's reactivity depends on how readily it forms an **ion** by losing electrons.

In the displacement reaction of copper sulfate and iron, iron forms an ion more easily than copper.

At the end of the reaction you are left with iron ions, not copper ions.

### Steps for writing an ionic equation (HT only)

- 1 check symbol equation is balanced
- 2 identify all aqueous ionic compounds
- 3 write those compounds out as ions
- 4 remove spectator ions.

### Reduction and oxidation: electrons (HT only)

Oxidation and reduction (**redox** reactions) can be defined in terms of oxygen, but can also be defined as the loss or gain of electrons.

Oxidation is the *loss* of electrons, and reduction is the *gain* of electrons.

In the example displacement reaction:

- iron atoms have been oxidised
- copper ions have been reduced.

### Acids and alkalis

**Acids** are compounds that, when dissolved in water, release  $\text{H}^{+}$  ions. There are three main acids: sulfuric acid  $\text{H}_2\text{SO}_4$ , nitric acid  $\text{HNO}_3$ , and hydrochloric acid  $\text{HCl}$ .

**Alkalis** are compounds that, when dissolved in water, release  $\text{OH}^{-}$  ions.

The **pH** scale is a measure of acidity and alkalinity. It runs from 1 to 14.

- Aqueous solutions with  $\text{pH} < 7$  are acidic.
- Aqueous solutions with  $\text{pH} > 7$  are alkaline.
- Aqueous solutions with  $\text{pH} = 7$  are neutral.

### Salts

When acids react with metals or metal compounds, they form salts.

A salt is a compound where the hydrogen from an acid has been replaced by a metal. For example nitric acid,  $\text{HNO}_3$ , reacts with sodium to form  $\text{NaNO}_3$ . The H in nitric acid is replaced with Na.

The table shows how to name salts.

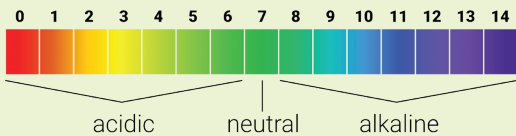
Acid	hydrochloric acid	sulfuric acid	nitric acid
Formula	HCl	$\text{H}_2\text{SO}_4$	$\text{HNO}_3$
Ions formed in solution	$\text{H}^{+}$ and $\text{Cl}^{-}$	$2\text{H}^{+}$ and $\text{SO}_4^{2-}$	$\text{H}^{+}$ and $\text{NO}_3^{-}$
Type of salt formed	metal chloride	metal sulfate	metal nitrate
Sodium salt example	sodium chloride, NaCl	sodium sulfate, $\text{Na}_2\text{SO}_4$	sodium nitrate, $\text{NaNO}_3$

### Indicators

Indicators can show if something is an acid or an alkali.

- **Universal indicator** can also tell us the approximate pH of a solution.
- Electronic pH probes can give us the exact pH of a solution.

#### The pH scale



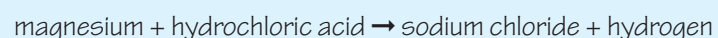
# Chapter 5: Chemical changes 2

## Knowledge organiser

### Reactions of acids

#### Reactions of acids with metals

Acids react with some metals to form salts and hydrogen gas.



#### Neutralisation reactions

##### Reactions of acids with metal hydroxides

Acids react with metal hydroxides to form salts and water.



The ionic equation for this reaction is always:



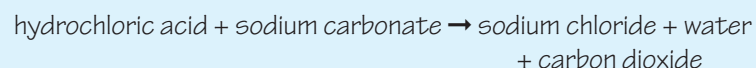
#### Reactions of acids with metal oxides

Acids react with metal oxides to form salts and water.



#### Reactions of acids with metal carbonates

Acids react with metal carbonates to form a salt, water, and carbon dioxide.



### Alkalis and bases

**Bases** neutralise acids to form water in **neutralisation** reactions. Some metal hydroxides dissolve in water to form alkaline solutions, called alkalis.

Some metal oxides and metal hydroxide do not dissolve in water. They are **bases**, but are not alkalis.

### Strong and weak acids

Sulfuric acid, nitric acid, and hydrochloric acid, are all **strong acids**. This means that, when dissolved in water, every molecule splits up into ions – they are completely ionised:

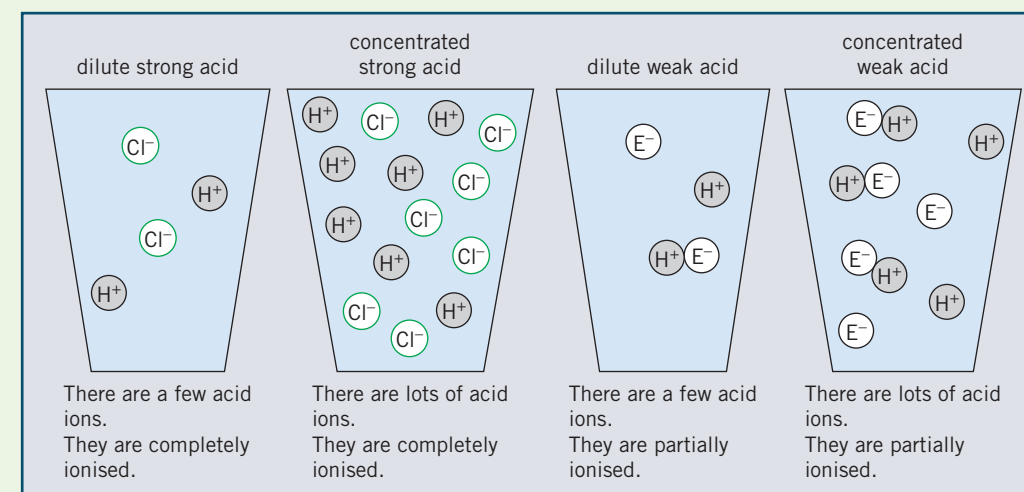
- $\text{H}_2\text{SO}_4(\text{aq}) \rightarrow 2\text{H}^+(\text{aq}) + \text{SO}_4^{2-}(\text{aq})$
- $\text{HNO}_3(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{NO}_3^-(\text{aq})$
- $\text{HCl}(\text{aq}) \rightarrow \text{H}^+(\text{aq}) + \text{Cl}^-(\text{aq})$

- Ethanoic acid, citric acid, and carbonic acid are **weak acids**. This means that only a percentage of their molecules split up into ions when dissolved in water – they are partially ionised.
- For a given concentration, the *stronger* the acid, the *lower* the pH.

### Concentrated and dilute acids

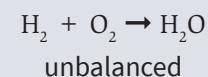
**Concentration** tells us how much of a substance there is dissolved in water:

- more concentrated acids have lots of acid in a small volume of water
- less concentrated acids (dilute acids) have little acid in a large volume of water.

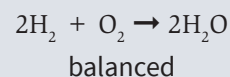
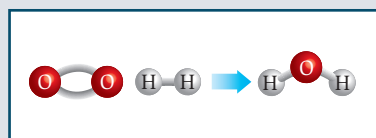


### Balancing symbol equations

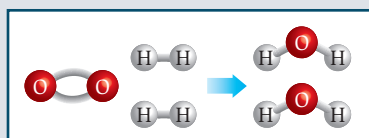
When writing symbol equations you need to ensure that the number of each atom on each side is equal.



there are 2 hydrogen atoms on each side, but 2 oxygen atoms in the reactants and 1 in the product



there are 4 hydrogen atoms on each side, and 2 oxygen atoms on each side



### State symbols

A balanced symbol equation should also include state symbols.

State	Symbol
solid	(s)
liquid	(l)
gas	(g)
aqueous or dissolved in water	(aq)



#### Key terms

Make sure you can write a definition for these key terms.

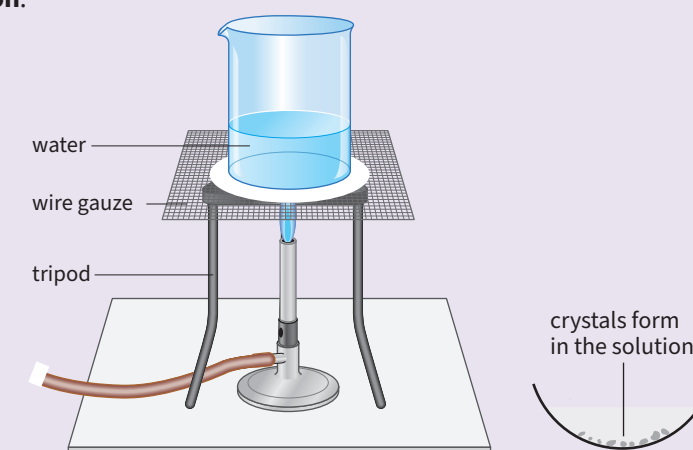
displacement metal ore electrolysis oxidation extraction reactivity spectator ion half equation reactivity series state symbols ion redox ionic equation reduction

### Crystallisation

You can produce a solid salt from an insoluble base by **crystallisation**.

The experimental method is:

- Choose the correct acid and base to produce the salt.
- Put some of the dilute acid into a flask. Heat gently with a Bunsen burner.
- Add a small amount of the base and stir.
- Keep adding the base until no more reacts – the base is now in excess.
- Filter to remove the unreacted base.
- Add the remaining solution to an evaporating dish.
- Use a water bath or electric heater to evaporate the water. The salt crystals will be left behind.



# Chapter 5: Chemical changes

## Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

C5 questions	Answers
1 What does reactivity mean?	how vigorously a substance chemically reacts
2 How can metals be ordered by their reactivity?	by comparing their reactions with water, acid, or oxygen
3 What name is given to a list of metals ordered by their reactivity?	reactivity series
4 In terms of electrons, what makes some metals more reactive than others?	they lose their outer shell electron(s) more easily
5 Why are gold and silver found naturally as elements in the Earth's crust?	they are very unreactive
6 What is an ore?	rock containing enough of a metal compound to be economically worth extracting
7 How are metals less reactive than carbon extracted from their ores?	reduction with carbon
8 In terms of oxygen, what is oxidation?	addition of oxygen
9 In terms of oxygen, what is reduction?	removal of oxygen
10 Why can metals like potassium and aluminium not be extracted by reduction with carbon?	they are more reactive than carbon
11 How are metals more reactive than carbon extracted from their ores?	electrolysis
12 What is a displacement reaction?	a more reactive substance takes the place of a less reactive substance in a compound
13 What is an ionic equation?	equation which gives some substances as ions and has spectator ions removed
14 What type of substance is given as ions in an ionic equation?	ionic compounds in solution (or liquid)
15 What is a spectator ion?	ion that is unchanged in a reaction
16 What is a half equation?	equation that shows whether a substance is losing or gaining electrons
17 In terms of electrons, what is oxidation?	loss of electrons
18 In terms of electrons, what is reduction?	gain of electrons

19 In terms of pH, what is an acid?	a solution with a pH of less than 7
20 In terms of pH, what is a neutral solution?	a solution with a pH of 7
21 In terms of H <sup>+</sup> ions, what is an acid?	a substance that releases H <sup>+</sup> ions when dissolved in water
22 How is the amount of H <sup>+</sup> ions in a solution related to its pH?	the more H <sup>+</sup> ions, the lower the pH
23 What are the names and formulae of three main acids?	hydrochloric acid, HCl; sulfuric acid, H <sub>2</sub> SO <sub>4</sub> ; nitric acid, HNO <sub>3</sub>
24 How do you measure the pH of a substance?	universal indicator or pH probe
25 What is a strong acid?	an acid where the molecules or ions completely ionise in water
26 What is a weak acid?	an acid where the molecules or ions partially ionise in water
27 What is a salt?	compound formed when a metal ion takes the place of a hydrogen ion in an acid
28 Which type of salts do sulfuric acid, hydrochloric acid, and nitric acid form?	sulfates, chlorides, nitrates
29 What are the products of a reaction between a metal and an acid?	salt + hydrogen
30 What are the products of a reaction between a metal hydroxide and an acid?	salt + water
31 What are the products of a reaction between a metal oxide and an acid?	salt + water
32 What are the products of a reaction between a metal carbonate and an acid?	salt + water + carbon dioxide
33 What is a base?	substance that reacts with acids in neutralisation reactions
34 What is an alkali?	substance that dissolves in water to form a solution above pH 7
35 What is a neutralisation reaction?	a reaction between an acid and a base to produce water
36 What is the ionic equation for a reaction between an acid and an alkali?	H <sup>+</sup> (aq) + OH <sup>-</sup> (aq) → H <sub>2</sub> O(l)
37 How can you obtain a solid salt from a solution?	crystallisation
38 When an acid reacts with a metal, which species is oxidised?	the metal
39 When an acid reacts with a metal, which species is reduced?	hydrogen
40 What are the four state symbols and what do they stand for?	(s) solid, (l) liquid, (g) gas, (aq) aqueous or dissolved in water