Unit 9F Patterns of reactivity

About the unit

In this unit pupils:
- learn that although metals react in a similar way with oxygen, water and acids, some react more readily than others
- establish and use a reactivity series for metals
- represent chemical reactions by word and/or symbol equations

In scientific enquiry pupils:
- use a proposed reactivity series to make predictions
- present qualitative data in a way which enables patterns to be described
- investigate the relative reactivity of different metals, identifying and controlling relevant variables

This unit is expected to take approximately 7.5 hours.

Where the unit fits in

This unit builds on unit 8E 'Atoms and elements', unit 8F 'Compounds and mixtures' and unit 9E 'Reactions of metals and metal compounds'.

Ideas in this unit are developed further in unit 9G 'Environmental chemistry' and unit 9H 'Using chemistry'.

The unit lays the foundation for work in key stage 4 on metals and their compounds.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: select and make effective use of secondary sources about the origins and uses of metals; identify relevant observations and describe patterns in these; suggest a workable approach to investigating the reaction of metals with acids, identifying variables to be controlled; explain results using scientific knowledge and understanding

some pupils will not have made so much progress and will: select information from secondary sources about the origins and uses of metals; describe observations and identify where there are similarities; suggest how reaction with acids might be investigated, controlling variables identified for them; relate results to scientific knowledge and understanding

some pupils will have progressed further and will: synthesise information from secondary sources; point out where reactions do not fit the pattern expected

in terms of materials and their properties

most pupils will: identify and describe similarities in chemical reactions; identify differences in the reactivity of different metals and use these to explain some everyday uses and occurrence of metals; represent chemical reactions by word equations

some pupils will not have made so much progress and will: describe how some metals react with water, acids and oxygen; give some uses of metals, relating these to the reactivity of the metal

some pupils will have progressed further and will: use the reactivity series to make predictions about the reactions of metals; relate the reactivity of a metal to its uses, how it occurs and when it was first extracted and used; represent some reactions by symbol equations

Prior learning

It is helpful if pupils:
- can explain the differences between elements and compounds
- have represented elements and compounds by symbols and formulae
- have represented chemical reactions by word equations
- have carried out tests to identify common gases
- know that many metals react with oxygen to form oxides
- can make generalisations about the reaction of metals with acids

Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:
- observe reactions of alkali metals
- use metals, acids and solutions of salts which may be hazardous
- use flammable metals and observe what happens when they burn
- observe the thermit reaction
- work with coarse mesh filings of metals
- plan and carry out their own investigation into the reaction of metals with acids

Model risk assessments used by most employers for normal science activities can be found in the publications listed in the *Teacher's guide*. Teachers need to follow these as indicated in the guidance notes for the activities, and consider what modifications are needed for individual classroom situations.

Language for learning

Through the activities in this unit pupils will be able to understand, use and spell correctly:
- words with different meanings in scientific and everyday contexts, *eg displacement, nature*
- words with a precise scientific meaning, *eg compound, reactivity, react, salt, equation, reactant, product*
- names of chemical compounds, *eg copper sulfate, magnesium nitrate, zinc chloride*
- words and phrases relating to scientific enquiry, *eg order of reactivity, qualitative observations*

Through the activities pupils could:
- identify information needed and use different texts as sources
- structure paragraphs to develop points, using evidence and additional facts

Resources

Resources include:
- photographs, videos or nearby examples of bronze statues or roofs that are covered with verdigris
- samples of other tarnished or corroded metal objects, *eg copper, silver, aluminium*
- photographs or samples of gold artefacts that have not corroded
- data tables for reactivity series
- materials for thermit reaction, safety equipment and Hazcards
- a video clip showing reactions of rubidium and caesium with water
- hazard warning labels for alkali metals

Out-of-school learning

Pupils could:
- look for examples of the everyday use of metals, identifying which metals are used and whether corrosion is a problem
- read news stories about metals, metal extraction and mining
- read fiction and poems, *eg 'Charcoal burners'*, about the search for metals
- read about alchemy and the quest to turn base metal into gold

1	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Why do metals tarnish?				
	• that many metals are affected by air and water • that different metals are affected in different ways • that some metals are soft and can be cut	• Show pupils a range of metal objects or pictures of objects, *eg copper and nickel coins, gold rings, an old gold necklace, a relatively new rusty hinge, a tarnished silver cup, a photograph of a bronze/copper roof,* and ask them to describe what has happened to each and what has caused this. Elicit ideas about the effect of air/water and the different effects on different metals. • Extend to show pieces of potassium, sodium and lithium, which are shiny when freshly cut but which immediately tarnish on exposure to air. Ask pupils to explain why the surfaces become dull. Challenge pupils to say whether these are metals or not, asking them to produce reasons for and against. Refer back to work on the periodic table.	• describe how metals change due to exposure to the air, *eg iron rusts, silver becomes dull, copper darkens* • identify some metals that corrode readily and some that do not • give a reason why sodium, potassium and lithium seem to be metals, *eg they are shiny*, and a reason why they seem not to be, *eg they are not hard, they can't be left in the air without tarnishing*	• It is helpful to contrast the permanent uncorroded state of gold, *eg an old gold necklace,* with the rapid corrosion of other metals, *eg a new iron hinge.* • In unit 8E 'Atoms and elements' pupils identified characteristics of metals and where they are placed in the periodic table. • Extension: a corrosion trail around the school could be constructed for pupils to follow on their own. ⚠ **Safety** – potassium, sodium and lithium are corrosive and highly flammable. Small pieces the size of rice grains should be used. Eye protection and safety screens should be used
How do metals react with water?				
	• that some metals react with cold water to produce hydrogen • that some metals react more readily with water than others • about the hazards associated with some metals	• Ask pupils whether metals react with water or not, giving their reasons. Invite them to explore the reaction of some familiar metals, *eg iron, zinc, magnesium, copper*. Ask pupils to predict whether the rapidly tarnishing metals seen in the previous activity would react with water. Demonstrate the reactions to test their predictions. • Use a safe method to show that hydrogen and an alkaline solution are produced, *eg place a small piece of lithium in a beaker of water and collect the gas produced in a test tube*. Ask pupils to identify similarities and differences in the reactions of potassium, sodium and lithium with water. Establish an order of reactivity of these metals and help pupils to write word equations. Extend by showing pupils a video clip of the reactions of rubidium and caesium with water. Compare the reactions of the alkali metals with those of the other metals used earlier and agree a tentative order of reactivity. Show pupils the hazard-warning labels on alkali metal containers and ask why they are kept under oil.	• identify evidence for a chemical reaction, *eg bubbles of gas, heat produced* • describe some similarities in the reactions, *eg hydrogen produced, pH shows alkali produced* • describe differences between the reactions, *eg flame produced with potassium but not with sodium or lithium* • identify an order of reactivity of the metals • describe and explain some of the safety precautions to be taken when dealing with reactive metals	• Teachers may wish to extend this work to the reactions of some metals with steam, but it is not necessary to do so. Eye protection and safety screens should be used. • Extension: pupils could be asked to find out how fires involving metals are dealt with. • Extension: pupils could be asked to write the symbols and formulae for reactants and products, and from these form symbol equations. ⚠ **Safety** – potassium, sodium and lithium are corrosive and highly flammable. Small pieces the size of rice grains should be used. Eye protection and safety screens should be used

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Is the order of reactivity of metals with water the same as that with acids?			
• that some metals react more readily with acids than others • to decide which observations are relevant to a piece of work	• Remind pupils of work they did in unit 9E 'Reactions of metals and metal compounds' on the reactions of acids with metals and ask them what is formed. Help them to write word equations. Ask pupils to carry out quick reactions between either sulfuric acid or hydrochloric acid and filings of coarse metal mesh, *eg copper, iron, zinc, magnesium*, and from their observations decide the order of reactivity. Ask them which observations they took account of, to compare the reactions of hydrochloric and sulfuric acid, and then to agree an order of reactivity. Compare this with what was established in the previous activity.	• identify relevant observations, *eg extent of bubbling, rise in temperature* • use observations to suggest an order of reactivity	• This activity is intended to be done quickly. There is an opportunity to investigate the reaction of some metals with acid later in the unit. • At this point it is sufficient to ensure that similar amounts of each metal and similar amounts of acid are used. After the activity, pupils could be asked to evaluate how confident they are in their results and to consider which variables to control. • Extension: pupils could be asked to write the symbols and formulae for reactants and products, and from these write symbol equations. ⚠ **Safety** – 0.4 mol dm^{-3} acid should be used. Eye protection should be worn. Hydrogen sulfide (toxic) may be formed in the reaction with iron. However, this is not usually a safety problem. Supervise the use of magnesium. Coarse-mesh magnesium is highly flammable

3	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
	Can we make predictions about the reactions of metals with oxygen?			
	• to use a proposed reactivity series to make predictions • to test predictions made • that metals react with oxygen to form oxides	• Remind pupils that metals also react with oxygen (or the oxygen in the air) to form oxides. Ask them about word equations. Ask pupils to use their proposed reactivity series to suggest how readily different metals would react, and then use a mixture of demonstration and video clips to test whether the predictions are supported. Point out that in establishing a reactivity series, more secure evidence than qualitative observations is needed. Establish with pupils that, in terms of the evidence collected, the order of reactivity of metals with oxygen is generally similar to that with water and with acids.	• use the reactivity series to make a sensible prediction, *eg sodium would be more reactive with oxygen than copper* • evaluate the evidence obtained, *eg magnesium reacted more violently than copper, but it was difficult to compare sodium and calcium* • state that all the metals tested produced oxides	• Extension: some pupils may be ready to look at quantitative data supporting an established reactivity series. In unit 9I 'Energy and electricity' pupils explore the voltage of simple cells with poles made from different metals. • Extension: pupils could be asked to write the symbols and formulae for reactants and products, and from these write symbol equations. ⚠ **Safety** – magnesium and some other metals are highly flammable. Risk assessments should be followed. Eye protection should be used. Avoid looking directly at burning magnesium. Safety screens should be used

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Can metals displace each other?			
• that a metal will displace a less reactive metal from a solution of one of its salts • to construct a table to show patterns clearly • to identify patterns in observations • to use a model to explain results	• Provide pupils with small samples of metals, *eg magnesium, iron, copper, zinc*, and solutions of metal salts, *eg zinc sulfate, iron (II) sulfate, copper sulfate, silver nitrate*. Ask pupils to plan tests of combinations of metal and metal salt to find out if there is a reaction, recording their results in a table. Ask pupils to find a pattern in their results and, if possible, to reorder their table to show the results more clearly. Discuss the results with the pupils and use an analogy or model to explain the displacement of the less reactive metal by the more reactive one. Ask pupils to predict whether other reactions will occur. • Show using an analogy, *eg 'pull' of metal on the sulfate,* and word or symbol equations that whether there is a reaction or not depends on the metal and the metal in the salt, not on the acid from which the salt was derived. • If appropriate, link to work pupils have done on the voltages of simple cells.	• identify where reactions occur and where they do not • relate their results to the position of the metal in the reactivity series • articulate the pattern, *eg it's the metal that's important; a metal high in the reactivity series will push out one lower down, but a lower one won't push out a higher one* • use an analogy or model to explain the results, *eg the zinc has a stronger pull on the sulfate than the copper does*	• Using very small quantities in a dimple tile works well. In some cases, *eg if magnesium is added to copper sulfate solution,* the reaction may be between the water and the metal rather than between the salt and the metal. • This activity provides an opportunity to use ICT to reorder tables of results. • This work could be extended to heating metals, *eg copper, zinc,* with metal oxides to determine whether there is a reaction. Some mixtures may be dangerous. • Although analogies, *eg 'pull' of metal,* are not strictly correct, they may be helpful to pupils in establishing principles about displacement. • Extension: pupils could be asked to write the symbols and formulae for reactants and products, and from these write symbol equations. ⚠ **Safety** – 0.4 mol dm^{-3} or 0.1 mol dm^{-3} solutions of salts can be used. Eye protection should be worn. – appropriate risk assessments should be followed before practical work begins
• that displacement reactions can be useful	• Demonstrate the thermit reaction between iron (III) oxide and aluminium. Ask pupils to explain where the energy to melt the iron produced comes from, and explain, *eg using a video clip,* the use of the reaction in welding. Use the displacement model to describe what is taking place during the reaction.	• explain that energy released by the reaction is sufficient to melt the iron • describe how molten iron is used in welding, *eg on railway lines*	⚠ **Safety** – an appropriate method should be used and a risk assessment followed. Safety screens and face shields should be used

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
Checking progress			
• how an activity series can help to make sense of the reactions of metals • how an activity series can be used to make predictions • that sometimes the data doesn't enable firm predictions/ conclusions to be made	• Provide pupils with an activity series of metals (including some that they haven't tested, *eg aluminium, lead, silver*) and help them make a summary sheet showing reactions of the metals. • Tell pupils the position in a series of an unknown metal and ask them to predict its reactions. Give pupils information about the reactions of metals not already in the series and ask them to predict where they might come. • Discuss with pupils any difficulties in coming to decisions.	• summarise reactions of metals, making use of patterns in the reactivity series • use the activity series to make predictions about the reactions of metals • identify where an element cannot be given a position or where a firm prediction cannot be made, giving reasons for the difficulty	• Extension: some pupils could be given quantitative data.
How does the activity series relate to uses and sources of metals?			
• to identify what information is needed, and use different texts as sources • to structure paragraphs to develop points, using evidence and additional facts • to relate the occurrence, extraction and use of metals to their position in the activity series	• Introduce the activity with a short video illustrating the range and uses, and possibly extraction, of metals. • Ask pupils to use secondary sources, together with their own knowledge of metals to find the answers to a series of questions of varying difficulty, *eg* – *Why is sodium not used for cutlery?* – *Why is a light metal like magnesium not used for car bodies?* – *Why has so much gold jewellery survived from ancient civilisations?* – *Why was bronze used before iron?* – *Aluminium is much more abundant than iron, so why wasn't it used until the beginning of the twentieth century?* – *Which metals are found naturally?* – *What are the sources of magnesium? Why is it not found naturally?* – *How are metals recycled?* • Ask pupils to present their findings and help them to organise the points to produce an information leaflet linking metals' reactivity to their uses (including when they were first used).	• identify key points relevant to the questions asked • make connections between reactivity and aspects of use, *eg aluminium is reactive, and therefore hard to extract – this is why it wasn't used as early as iron*	• In unit 9E 'Reactions of metals and metal compounds' pupils will have found out something about uses and sources of metals. This activity extends that work by relating it to the reactivity series. • Pupils should be encouraged not to look in too much detail at extraction processes, but to identify the key point about the method, *eg electrolysis, smelting with carbon*. • Information about copper can be found on the internet, *eg at www.copper.org*

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
How can we find out more about the reaction of metals with acids?			
• to decide which observations or measurements are appropriate • to identify variables that need to be controlled and decide how to do this • to choose axes and scales for graphs • to decide whether results that do not fit the pattern expected arise from experimental shortcomings or are significant • to explain results in the light of scientific knowledge and understanding	• Review what pupils remember about the reactions of acids with metals and remind them of how they compared their reactivity. Explain that they are going to investigate more systematically the differences in reactivity of zinc, magnesium and aluminium with hydrochloric acid. Discuss the indicators, *eg changes in temperature, amount of gas produced,* that might be measured and which variables they will need to control. Help pupils plan and carry out their investigations safely and, where appropriate, present their results as graphs. Ask pupils to tell the story of what the graphs show and to explain whether the results are what they expected from the relative positions of the metals in the reactivity series. Remind them of earlier work on the extraction of aluminium. Discuss with pupils the key points in this investigation and help them to write an account that brings these out clearly.	• identify a workable procedure, *eg to measure the temperature of the reacting mixture every minute for 10 minutes* • identify variables that need to be controlled, *eg quantity of metal, volume of acid* • present results clearly and appropriately • explain the results obtained in the light of the reactivity series and knowledge about aluminium	• If pupils devise their own methods for this investigation, they may choose measures that compare the rates of the reactions rather than the reactivity of the metals. Some teachers may wish to discuss this with some pupils. ⚠ **Safety** – 0.4 mol dm^{-3} acid and coarse-mesh filings of the metal can be used. Eye protection should be worn. Coarse-mesh magnesium and aluminium are highly flammable. Supervise this investigation closely – pupils' plans should be checked for health and safety before practical work begins
Reviewing work			
• key ideas about the relative reactivity of different metals • how to apply the ideas • how to recognise what information questions are seeking and to evaluate answers	• Prepare a short test on the content of the unit, *eg using comprehension and data-handling questions about different metals,* together with additional questions to provide practice materials. Discuss the additional questions with pupils, *eg by asking them to read questions out loud*, discuss what the questions mean and what sort of answers are required before they take the test. When pupils have taken the test and it has been marked, discuss their answers to the test questions in a similar way. Provide real (or made-up) answers to some questions and ask pupils to identify good and bad points in each.	• recall key ideas about the relative reactivity of different metals • use and apply these ideas in different contexts • identify how sample answers provide, or do not provide, the information required	