Unit 9E Reactions of metals and metal compounds

About the unit

In this unit pupils:
- explore the properties of metals and non-metals
- learn that different acids react in similar ways with metals, with metal carbonates and with metal oxides
- represent elements by symbols and compounds by formulae
- use word and symbol equations to describe these reactions

In scientific enquiry pupils:
- describe patterns in qualitative data about reactions
- use patterns in reactions to make predictions about other reactions
- devise and evaluate a method for preparing a sample of a specified salt

This unit is expected to take approximately 7.5 hours.

Where the unit fits in

This unit builds on unit 8E 'Atoms and elements' and unit 8F 'Compounds and mixtures'.

In unit 7E 'Acids and alkalis', pupils will have observed neutralisation reactions, and in unit 7F 'Simple chemical reactions', they will have identified that there are chemical reactions between acids and metals and between acids and carbonates. However, they are unlikely to have considered the other products of these reactions. With some pupils, teachers may wish to concentrate on some of the new topics, extending activities, and with others to spend more time on revision of previous work.

This unit lays the foundation for unit 9F 'Patterns of reactivity'.

Expectations

At the end of this unit

in terms of scientific enquiry

most pupils will: make observations and use these to identify similarities in chemical reactions; use preliminary work to decide on a method for preparing a salt and suggest ways in which their method could be improved

some pupils will not have made so much progress and will: make observations of chemical reactions, and show that there are patterns in these; identify where they found difficulties in preparing a salt

some pupils will have progressed further and will: explain the steps they took to prepare a high-quality sample of a salt

in terms of materials and their properties

most pupils will: describe how metals react with acids and how acids react with metal carbonates, metal oxides and alkalis; identify evidence which indicates that a chemical reaction has taken place; represent reactions by word equations, identify patterns in these and produce general equations; name a variety of salts and describe the uses of some of them

some pupils will not have made so much progress and will: identify that hydrogen is produced when many metals react with acids, and carbon dioxide when acids react with carbonates, and describe tests for hydrogen and carbon dioxide; state that the production of a new material is evidence of a chemical reaction

some pupils will have progressed further and will: represent chemical compounds by formulae and combine these into symbol equations; use knowledge of reactions to make predictions about other reactions

Prior learning

It is helpful if pupils:

- can name some metals, understanding that they are elements, and can give some of their characteristics
- know that atoms join together in different ways when chemical reactions take place
- have represented some elements and compounds by symbols and formulae
- understand that chemical reactions can be represented by word, particle and symbol equations
- have carried out tests to identify hydrogen and carbon dioxide

Health and safety

Risk assessments are required for any hazardous activity. In this unit pupils:

- explore the properties of metallic and non-metallic elements
- use solutions of acids, alkalis and metal salts, which may be hazardous
- evaporate salt solutions prepared in a variety of ways
- plan and carry out an investigation into the preparation of a salt

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:

- names of compounds, including salts, *eg magnesium sulphate, copper carbonate, copper nitrate, sodium chloride, potassium nitrate,* recognising that the whole name is needed to specify a compound
- words with different meanings in scientific and everyday contexts, *eg salt, reaction, product*
- words and phrases relating to scientific enquiry, *eg visible change, evidence of reaction*

Through the activities pupils could:

- organise content into a whole piece of writing with the relationship between points and/or paragraphs clearly signalled
- structure paragraphs to develop points by using evidence and additional facts

Resources

Resources include:

- information about metals
- cards showing names of acids, alkalis, metal carbonates, metal oxides and metals
- cards showing names of salts that can be safely prepared
- information about hazards of salts and starting materials for their preparation
- two accounts of the preparation of a salt, one that effectively evaluates the method and product, *eg mass, appearance of crystals,* and one that does not
- secondary sources providing information about the uses of salts

Out-of-school learning

Pupils could look for examples of:

- metal corrosion in the locality
- the use of metal compounds in everyday products

1	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
	Why are metals useful?			
	• that metals are good conductors of heat and electricity • that most non-metallic elements are poor conductors of heat and electricity • about the range of metals, their uses and where they are found • to use and combine data from a variety of information sources • to organise facts/ideas/ information into an appropriate sequence	• Provide pupils with a range of questions about metals and non-metals, *eg* *– Are metals good conductors of heat/electricity?* *– Are non-metals non-conductors?* *– Are non-metals all gases?* *– Where do we get metals (iron, zinc, copper, lead, gold, silver) from?* *– What are they used for?* Suggest sources of information they could use, *eg databases, reference books, practical activities*. • Ask different groups to explore different questions and to produce a factsheet about a particular element or property. Help pupils use these to make a comparison of non-metals and metals and to explain what makes metals useful. • Explain to pupils that there are similarities in the ways in which metals react chemically and that they are going to find out more about these in this unit.	• contrast the conductivity of metals and non-metals • identify graphite as a non-metallic conductor • produce an information sheet that is correct and well sequenced and contains appropriate information • make some generalisations about the properties of metals which make them useful, *eg they are hard, they can be flexible*	• Pupils often confuse non-metallic elements with other non-metallic materials. It is helpful to restrict this activity to elements. • Some pupils will need to do more work to consolidate their ideas about differences between metals and non-metallic elements, while others will be able to move on to consider the chemical reactions of metals and acids and to begin to represent these symbolically. Teachers will need to decide which parts of the unit to emphasise. • This activity offers an opportunity to construct a class database about metals and non-metals. This could be used as a starting point for another class. • Extension: pupils could be asked to find out about ways in which metals have been used in the past, *eg in jewellery*. ⚠ **Safety** – if practical activities are included, appropriate risk assessments must be followed

2	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note

What happens when metals react with acids?

- that some metals react with dilute acids to form salts and release hydrogen
- to carry out a test for hydrogen
- to represent the reactions of metals with dilute acids by word equations
- to identify patterns in reactions between metals and dilute acids
- to use patterns in reactions to make predictions about other reactions

- Demonstrate that a metal, *eg zinc*, reacts with both hydrochloric acid and sulphuric acid to produce a gas. Establish that the bubbles indicate that a gas is being formed, that this is a new material and that a chemical reaction is taking place. Show pupils the formulae for the two acids and ask them to suggest what the gas might be. Remind them of the test for hydrogen and demonstrate that hydrogen is formed.
- Ask pupils to find out whether similar reactions occur when other metals, *eg magnesium, iron,* react with hydrochloric acid and to record their results in a table. Establish that hydrogen is produced in each case and, using the names, symbols and formulae for the reactants and hydrogen, ask pupils to suggest what has happened to the metal and where the other product might be found. Using appropriate sample(s), show by evaporation that the salt remains in solution. Using the patterns in the equations, ask pupils to predict what will be made when calcium reacts with hydrochloric and sulphuric acids. Demonstrate the reactions, showing that hydrogen is made.

- identify the gas produced in the reaction between metals and acids as hydrogen
- write word equations for the reactions and explain the similarities between them
- use the formulae of the reactants and products to explain how atoms join in different ways as a result of the reaction
- predict that hydrogen and the appropriate salt will be made as a result of the reaction

- When calcium is used with sulphuric acid, there will be very little reaction because insoluble calcium sulphate is formed.
- From their work on this and the following activities, pupils could make a display showing equations for the reactions they have carried out and including samples of reactants and products.
- In unit 7F 'Simple chemical reactions' pupils will have explored the formation of hydrogen, but are less likely to have considered the other products of the reactions. The emphasis in this activity should be on the patterns in the products formed and in the equations.

⚠ **Safety**
– 0.4 mol dm^{-3} solutions of acid are suitable. Eye protection should be used. Ensure that excess metal is used so that the acids are not evaporated
– if iron is used, some toxic hydrogen sulphide is likely to be produced
– use only one granule of calcium

3	Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note

How do acids react with metal carbonates?

- that acids react with metal carbonates, producing carbon dioxide and a salt
- that production of new materials and energy changes are evidence of chemical reactions

- Ask pupils to explore what happens when acids, *eg hydrochloric, sulphuric, nitric*, react with a range of carbonates, *eg sodium carbonate, calcium carbonate, copper carbonate*. Prompt them with a series of questions, *eg*
  – *What is similar about the reactions?*
  – *Is a gas made? How do you know and what is it?*
  – *Are there colour changes?*
  – *Does the test tube get hot or cold?*
- Ask pupils to record their observations systematically and to record evidence of a chemical reaction taking place.
- Give pupils the formulae of a variety of metal carbonates and their corresponding chlorides, sulphates and nitrates, and invite pupils in groups to work out the products of some reactions between metal carbonates and acids. Help them to construct word equations. Collect and discuss their predictions, look for any patterns and establish the general word equation.

- identify the gas produced as carbon dioxide
- identify evidence for a chemical reaction, *eg a gas is produced, the test tube is getting hot*
- represent reactions by word equations
- identify the pattern in word equations and produce a general equation

- In unit 7F 'Simple chemical reactions' pupils are likely to have reacted acids with carbonates and tested for carbon dioxide produced, but are less likely to have considered the other products of the reaction. Pupils will have investigated different samples of limestone through their reaction with acid in unit 8H 'The rock cycle'.
- Pupils will have considered burning/oxidation as a reaction in which energy is released in unit 7I 'Energy resources' and unit 8B 'Respiration'. This unit is the first in which they will have considered energy release as indicative of a chemical reaction.
- In the activities in this unit, it may be helpful to emphasise that nitrate and sulphate, and sometimes carbonate, are 'groups' which often stay together in chemical reactions.
- Teachers may wish to help some pupils represent these reactions by symbol equations.
- Extension: pupils who have some familiarity with formulae and symbol equations could be given a short passage in a foreign language containing a number of equations. Their ability to explain it demonstrates the universality of chemical formulae and equations.

⚠ **Safety** – 0.4 mol dm^{-3} solutions of acid are suitable. 0.4 mol dm^{-3} hydrochloric acid is low hazard, 0.4 mol dm^{-3} sulphuric acid is low hazard and 0.4 mol dm^{-3} nitric acid is irritant

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What evidence is there of a chemical reaction between acids and metal oxides?			
• that acids react with metal oxides, producing a salt and water • that production of the salt is evidence of a chemical reaction • to represent reactions of acids with metal oxides by word equations	• Demonstrate, or ask pupils to carry out, a reaction between a metal oxide and an acid (preferably one that produces a coloured salt, *eg copper sulphate*) and ask pupils for evidence that a chemical reaction has taken place. Separate any excess metal oxide, reminding pupils how to use filtration apparatus, and evaporate the water. Compare the salt formed with a stock sample. • Help pupils to construct a word equation and, by using the formula, to identify the other product. Ask pupils to explain why this reaction did not produce bubbles. Give pupils the names of some other salts and ask them to suggest which acid and metal oxide would be needed to make them. Display suggestions and ask others to explain whether they are correct or not.	• identify evidence for a chemical reaction, *eg crystals are made, which are a different colour from what we started with* • represent reactions by word equations • identify the patterns in word equations and produce a general equation	• Extension: some pupils might investigate what happens to the pH of the acid when the metal oxide is added. This could provide an opportunity for datalogging using ICT. • Extension: this offers further opportunities for some pupils to practise writing formulae and symbol equations. ⚠ **Safety** – 0.4 mol dm^{-3} acid is suitable. Eye protection should be worn. Ensure pupils use excess oxide so that acid is not evaporated. Sometimes the reaction is very slow towards the end and not all of the acid is used up – do not use nickel oxide, which is toxic and a grade 1 carcinogen
Checking progress			
• to summarise how acids react with metals, metal carbonates and metal oxides	• Ask pupils to work in groups to make individual cards with the names of each reactant, plus signs, arrows and the names of each product for two examples of each of these reactions: acids with metals, acids with metal carbonates, and acids with metal oxides. Each group then shuffles its cards and passes them to another group, which has to sort them into three pairs of word equations, representing three types of reaction of acids, and to write the word, symbol and general equations for their own reactions.	• construct word equations for reactions • translate word equations into symbol equations • construct general equations for these reactions	

Learning objectives Pupils should learn:	Possible teaching activities	Learning outcomes Pupils:	Points to note
What is a salt?			
• that when an alkali is added to an acid, neutralisation takes place • how to obtain a neutral solution from an acid and an alkali • the hazards associated with alkalis	• Remind pupils of work they did earlier on acids and alkalis and establish by quick questioning what they recall. If necessary, demonstrate the use of universal indicator to determine the acidity or alkalinity of a solution. Ask pupils about neutralisation and establish that a neutral solution is one with pH7 and that neutralisation is a chemical reaction. Remind pupils about everyday examples of neutralisation. Explain to pupils that they are going to neutralise hydrochloric acid with potassium hydroxide or sodium hydroxide and to find out exactly how much to add. Ask them to suggest how they could do this and adopt an appropriate technique. Point out the risks of using alkalis. • Help pupils to carry out or demonstrate the reaction. Establish that potassium chloride or sodium chloride is formed, that sodium chloride is common salt and is an example of the class of compounds called 'salts'. Ask pupils to complete word equations for other neutralisation reactions.	• identify that a solution of pH7 is neutral • explain the safety precautions that need to be taken when using alkalis • use the technique adopted to obtain a neutral solution from which sodium chloride can be isolated • represent reactions by word equations • identify the pattern in word equations and produce a general equation, *eg acid + alkali → salt + water*	• Pupils will have used universal indicator and pH as a measure of acidity in unit 7E 'Acids and alkalis'. • If a class information folder was built up during unit 7E 'Acids and alkalis', this could be referred to. Pupils could be asked to try to find other everyday examples of neutralisation. • This activity provides an opportunity to use a pH probe and/or to introduce pupils to the use of a burette. A computer simulation might also be useful. • Pupils are often confused by the uses of the word 'salt'. Teachers may therefore prefer to make potassium chloride and discuss this as an example of a salt that is not common salt. Pupils need practice in distinguishing salts from other types of compound. • Extension: this activity offers further opportunities for some pupils to practise writing formulae and symbol equations. ⚠ **Safety** – 0.1 mol dm^{-3} solutions of acid and alkali are suitable for this activity. At this concentration sodium hydroxide and potassium hydroxide are irritant. Mouth pipettes should not be used
• that there are many different salts • that many salts are useful compounds	• List the names of salts already encountered in this unit and ask pupils to work out what the names show, *eg a part comes from a metal and a part comes from an acid*. Ask pupils to use secondary sources to find out the uses of some salts, *eg sodium stearate, potassium nitrate, copper sulphate, calcium phosphate, iron sulphate, magnesium sulphate, silver nitrate.*	• name a variety of salts • give the uses of a variety of salts	• Extension: pupils could be asked to find out the names of salts in household products or medicines.

6	Learning objectives	Possible teaching activities	Learning outcomes	Points to note
	Pupils should learn:		Pupils:	
	• to use preliminary work to find out if a possible approach is practicable • to use common laboratory equipment safely and effectively • to evaluate the methods used in terms of the quality of the salt made • to organise content into a piece of writing, with the relationship between paragraphs clearly signalled	• Prepare cards with the names of some salts that pupils can make easily and another selection of cards with the names of metals or metal compounds that can be used in the preparation. Give groups of pupils a 'salt' card and ask them to select an appropriate 'metal' or 'metal compound' card and to decide which acid they need to use. Include information about the hazards of the starting materials and salts named on the cards. Ask them to make a plan for preparing a sample of the salt. If appropriate, prompt them with a series of questions, *eg* *– How will you know when all the acid has reacted?* *– How will you separate any unreacted solid?* *– What will you do to try to get large crystals?* • Encourage pupils to try things out, *eg finding out if there is a visible change or if the reactant needs to be heated,* and then to prepare their salt. Ask pupils to produce an account of what they did, indicating any difficulties and saying what they did about them.	• decide whether they need to modify their plan • obtain a satisfactory sample of the salt • identify where they found problems and the effect these had on their product • produce an account of their work which identifies problems and corrects these, with clear explanations of how they were dealt with • write, using evidence, in paragraphs that develop points	• It may be helpful, before and/or after pupils write their accounts, to ask them to compare some other accounts (either from another class or prepared for the purpose). ⚠ **Safety** – teachers will need to check pupils' plans for health and safety before practical work begins. The main concern is to avoid the production of acid fumes if pupils try to evaporate solutions still containing acid – suitable salts to prepare include copper sulphate and copper nitrate from the metal oxide or carbonate; magnesium sulphate and zinc nitrate from the metal, metal oxide or carbonate. Nitrates may present problems on evaporating to dryness, when nitrogen dioxide might be formed
	Reviewing work			
	• to identify key points about the reactions of metals and acids • to identify patterns in the chemical reactions	• Ask pupils to write four or five multiple-choice questions on the work in this unit, clearly identifying the correct answer. Discuss questions with pupils and pass them to others to answer. Review questions with pupils and help them to produce a set with correct answers highlighted. • Help pupils to collect together and display all the summaries of reactions they have carried out during this unit.	• make generalisations about reactions of acids and metals, using chemical names for products and reactants	