

# The formation of compounds and chemical reactions

Published schemes generally have a limited range of practical work to illustrate the formation of compounds from elements. The combination of iron and sulphur into iron sulphide is a commonly cited example. In this practical work the differences between the following are stressed:

- iron sulphide
- iron
- sulphur
- an iron and sulphur mixture.

Practical work and related teaching about the formation of compounds from elements should be used to emphasise a number of important differences between compounds and their constituent elements and mixtures of elements.

- The elements in a compound are combined in a fixed proportion (usually a simple ratio) whereas in a mixture the proportions can be varied at will. (This ratio is shown in the chemical formula of the compound.)
- Compounds do not usually resemble their constituent elements in either chemical or physical properties.
- The component elements cannot easily be separated from the compound by physical means, e.g. magnetism, filtration, distillation. Although a new substance has been formed, no new matter has been created. The same atoms are still present, but have just been rearranged.
- The name of the compound signifies the constituent elements and reflects the fact that new matter has not been magically created. The '-ate' suffix signifies the presence of oxygen in the compound and the '-ide' suffix signifies the absence of additional oxygen; copper sulphate and copper sulphide for example. At this level the '-ite' suffix can denote a smaller proportion of the oxygen than '-ate', but at more advanced levels of chemistry a more precise nomenclature is used.

## Reflection

There is a considerable range of possible additional practical work that could be used to illustrate the formation of compounds.

- Are there some alternatives pieces of practical work to those that you usually use?
- Ask a colleague who is experienced in chemistry to demonstrate some of these possible pieces of practical work to you.

Points to emphasise when teaching this:

- compounds need not resemble their constituent elements
- elements are not easily separated again
- no new matter is created
- names of the compounds usually signify the constituent elements
- elements combine in fixed proportions (unlike mixtures).

*Please note that the reference sections or Hazcards numbers may change slightly as new editions are produced.*

Those who are not experienced with chemical reactions must rehearse these procedures. Teachers should not do a demonstration for the first time in front of a class. See CLEAPSS *Hazcards and Laboratory handbook* section 13.1 (only available to members of CLEAPSS) on accepted practice when handling chemicals and consult the science department's risk assessment. Eye protection is required for all these activities. Useful advice on health and safety in school science is available from several other sources, including: *Safety in science education* (DfEE, 1996; ISBN 011270915); *Hazardous chemicals for science education* (SSERC, 1997 but updated regularly); *Safeguards in the school laboratory* (ASE, 1996; ISBN 0863572502) and other ASE publications.

Compound	Outline details	References
Aluminium chloride	Chlorine is passed over very hot aluminium and yellow aluminium chloride is formed. Use a fume cupboard.	CLEAPSS Laboratory handbook section 13.2 Chlorine is toxic and irritant Hazcards 2 and 22
Aluminium iodine	A weighed mixture of aluminium powder and iodine is placed on a heat-proof mat in a fume cupboard. The vigorous reaction is initiated by adding a few drops of water. Purple fumes of iodine are produced, leaving behind a white dust containing aluminium iodine. (However, much of the product is aluminium oxide from combustion in air.) A demonstration.	Classic chemistry demonstrations page 207 Iodine is harmful Hazard 54
Calcium oxide	Place a granule of calcium on four layers of heat-proof paper. At arm's length, direct a flame from a kitchen torch. A very bright red light is formed. White calcium oxide powder is formed.	CLEAPSS guide L195 Wear a face shield and thermal glove.

Compound	Outline details	References
Carbon dioxide	Heat charcoal on a deflagrating spoon to red heat and place it in a gas jar of oxygen. Carbon dioxide is formed but there is little visible sign of this.	Hazard 69
Copper chloride	When a sheet of Dutch metal foil (copper/zinc alloy) is introduced into a gas jar of chlorine it spontaneously ignites forming clouds of product, including copper chloride. A demonstration.	Chlorine is toxic and irritant. Must be done in a fume cupboard. Hazard 22 and 27
Copper chloride decomposition	The electrolysis of $0.1 \text{ mol dm}^{-3}$ copper chloride solution with carbon electrodes to produce copper and chlorine can be carried out as a class practical.	Hazard 22 and 27. Once the chlorine has been detected using starch/iodide paper or bleaching moist litmus paper, the reaction should be stopped. Do not use currents in excess of 0.5A.
Copper oxide	If copper foil is heated in a Bunsen flame a layer of black copper oxide is formed. If the foil is folded into an envelope before heating, the difference between the copper oxide layer and the unchanged copper inside can be seen clearly when the envelope is unfolded.	Classic chemistry experiments page 59
Copper sulphide	This can be carried out on a small scale as a class practical. Prepared quantities of a copper and sulphur mixture are heated in an ignition tube with a mineral wool plug.	QCA scheme of work unit 8E Hazard 96
Iron iodide	0.5g of iodine in a boiling tube is gently vaporised and iron wool above it is strongly heated to initiate the reaction. Brown iron(III) iodide is formed. A fume cupboard is needed for this demonstration.	Classic chemistry demonstrations page 204 Iodine is harmful. Hazard 54

4 The National Strategies | Secondary  
 Strengthening teaching and learning of particle theory:  
 The formation of compounds and chemical reactions

Compound	Outline details	References
Iron oxide	Small tufts of iron wool can be burned in air as a class practical. A larger tuft can be burned in a gas jar of oxygen as a demonstration. Finely powdered iron can be prepared (from iron(II) ethanedioate) which can be demonstrated to ignite spontaneously when it is sprinkled out onto a heat-proof mat and forms brown iron (III) oxide.	Classic chemistry demonstrations page 155
Iron sulphide	Iron filings and sulphur can be mixed and separated again with a magnet. When strongly heated they combine to form iron sulphide. (The product is still magnetic unfortunately.) Class practical if appropriate procedure is used.	QCA scheme of work unit 8F Classic chemistry experiments page 35 CLEAPSS guide L195. This procedure must not be carried out on open bottle tops, heat-proof paper, etc. Use a small test-tube fitted with a mineral wool plug. Hazard 96
Iron (III) bromide	About 0.2ml of bromide is placed in a borosilicate test-tube. Iron wool is placed in the centre of the test-tube. The iron wool is heated. It glows red hot as the bromide fumes react with the iron. A demonstration.	A fume cupboard must be used. CLEAPSS Laboratory handbook section 13.2 Bromine is very toxic and corrosive. Dealing with bromine must be done very carefully and practised. Hazard 15
Iron (III) chloride	Using tongs, place hot iron wool in a gas jar of chlorine. Brown fumes of iron (III) chloride are produced. A demonstration.	CLEAPSS Laboratory handbook section 13.2 Chlorine is toxic and irritant. Hazard 22

Compound	Outline details	References
Lead bromide decomposition	Electrolyse a saturated solution of lead bromide with carbon electrodes. Lead is produced at the cathode and red bromine appears at the anode. A demonstration.	Stop the electrolysis once the chemical changes have been demonstrated. The solubility of lead bromide is 0.84g in 100ml of water. Hazcards 15 and 57
Magnesium oxide	Pupils can burn magnesium ribbon in the oxygen of the air and compare the resulting white magnesium oxide with the original elements. A class practical if eye protection is worn and pupils do not look directly at the flame.	QCA scheme of work unit 8E Hazard 59
Phosphorus (V) oxide	Red phosphorus can be heated on a deflagrating spoon and placed into a jar of oxygen. Clouds of phosphorus (V) oxide are formed. A demonstration.	CLEAPSS Laboratory handbook section 13.2 Red phosphorus is highly flammable. Hazcards 69 and 73
Silver oxide decomposition	If silver oxide is heated, silver is produced and oxygen is driven off.	Silver oxide is made by adding small drops of $2\text{mol dm}^{-3}$ sodium hydroxide solution (corrosive) to $0.1\text{ mol dm}^{-3}$ silver nitrate solution and filtering. Hazcards 87 and 91
Sodium chloride	A gas jar of chlorine can be inverted over a piece of sodium that has been heated on a fire brick. White sodium chloride is formed and collects on the wall of a gas jar. A demonstration.	QCA scheme of work unit 8E CLEAPSS guide L195 Chlorine is toxic and irritant. Sodium is highly flammable and corrosive. Hazcards 88 and 22

6 The National Strategies | Secondary  
 Strengthening teaching and learning of particle theory:  
 The formation of compounds and chemical reactions

Compound	Outline details	References
Sodium oxide	Sodium is heated in a deflagrating spoon so it burns and is placed in a gas jar of oxygen. White sodium, oxide is formed. A demonstration.	CLEAPSS Laboratory handbook section 13.2 Sodium is highly flammable and corrosive. Hazcards 69 and 88
Sulphur dioxide	Place sulphur in a deflagrating spoon. Heat until it burns and plunge it into a jar of oxygen. It burns with a bright blue flame to form a gas, sulphur dioxide. A demonstration.	Sulphur dioxide is toxic and corrosive. Hazcards 69 and 96
Tin (II) bromide	Place 0.5ml of bromine in a borosilicate test-tube. Add a piece of tin. An exothermic reaction starts. A fume cupboard must be used.	CLEAPSS Laboratory handbook section 13.2 Bromine is very toxic and corrosive. dealing with bromine must be done very carefully and practised. Wear protective gloves. Hazard 15
Water	Small quantities of hydrogen and oxygen mixture can be exploded as a demonstration. Hydrogen from a cylinder can be burned in air and water collected from the flame.	QCA scheme of work unit 8E Classic chemistry demonstrations pages 88 and 164 Hazard 48 CLEAPSS guide L195
Water decomposition	Water, containing sodium sulphate, is separated into hydrogen and oxygen by electrolysis. Use platinum or nickel electrodes if you wish to collect a pure sample of oxygen at the anode.	Classic chemistry experiments page 177, gives an interesting variation. CLEAPSS guide L195

Compound	Outline details	References
Zinc chloride composition	Anhydrous zinc chloride has a sufficiently low melting point for it to be decomposed into zinc chlorine by electrolysis as a demonstration.  Alternatively, 0.1 mol dm <sup>-3</sup> zinc chloride solution decomposes using carbon electrodes and produces zinc metal on the cathode and chlorine at the anode.	CLEAPSS guide L195 Hazardcards 22 and 108
Zinc iodide	Zinc powder mixed with iodine is used and the reaction is initiated with a few drops of ethanol. It can be adapted to a class practical.	Classic chemistry experiments page 44 Iodine is harmful. Zinc is flammable. Hazardcards 54 and 107
Zinc sulphate	The vigorous reaction between a freshly prepared mixture of zinc powder and sulphur makes a lively demonstration when appropriate safety precautions are taken. Do not carry out in fume cupboard, but at the end of the lesson in a well-ventilated laboratory.	Zinc is flammable. Hazardcards 96 and 107

In the latter part of Key Stage 3 teaching about particles often includes:

- chemical reactions and particle rearrangements
- conservation of mass
- using word equations and predicting simple reactions
- types of chemical reactions, e.g. neutralisation; reactions of metals.

This is reflected in the yearly learning objectives for Year 9 of 3.2 Chemical reactions in the science Framework. In Key Stage 4 this is usually extended to include:

- moving from word equations to symbol equations
- developing the model of an atom to one that comprises protons, neutrons and electrons
- rearrangement of bonds between atoms
- using patterns of reactivity
- using the particle model to predict outcomes of reactions.

There are also a number of misconceptions linked to this aspect of chemistry.

- Particles are destroyed when a substance is burned, so it loses mass.
- Compounds are mixtures. The elements can be mixed in any proportions.
- The name isn't systematically related to the constituent elements.
- Reactions where gases are formed result in a loss of mass.
- When two elements react together the atoms from the reactants are transmuted into new atoms (of the products). The reaction is a 'magical' change.

**Conservation of mass** is an essential concept at this stage in pupils' learning. It underlies all the subsequent development of ideas of chemical reactions by rearrangement of particles and chemical equations.

## Task 12: Illustrating the conservation of mass

If you are working with a colleague, jointly try these two demonstrations in a laboratory or prep room. Or ask a colleague experienced in this subject to help you try out these demonstrations.

### 1. Reaction of effervescent tablets

#### Materials

Eye protection

Large plastic fizzy drink bottle

50cm<sup>3</sup> water

Effervescent tablets

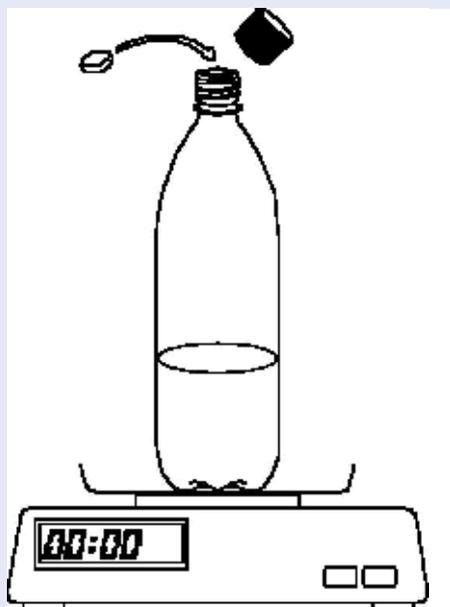
Top pan balance with large display

Computer with data logging and display software, if possible

#### Method

Assemble the apparatus as shown. Add the tablet to the water in the bottle and replace the cap securely to give a gas-tight fit. It may be necessary to break the tablet into two in order to get it through the neck of the bottle. Observe the mass of the bottle as the reaction proceeds.

If the top pan balance is interfaced to the computer the mass can be graphed or displayed for participants to see clearly.



Although the reading of the top pan balance will be marginally affected as the bottle inflates and receives slightly more upthrust from the surrounding air, the displayed mass will remain almost the same.

Pupils frequently believe that reactions involving the production of a gas result in a decrease in mass. Repeating this demonstration with the bottle cap loose, to allow the escape of gas, will show the difference between closed and open systems.

The point should be made that in the closed system no matter is destroyed or lost. The atoms have been rearranged, and some are now in the form of a gas (carbon dioxide), but there is the same number of atoms present in the bottle at the end as at the start. Matter has been conserved.

## 2. The 'blue bottle' experiment

### Description

A colourless solution in a flask is shaken. It turns blue and then gradually back to colourless but the mass remains constant. The cycle can be repeated many times.

### Apparatus

Eye protection

One 1dm<sup>3</sup> conical flask with stopper

Top pan balance, preferably with large digital display

8g of potassium hydroxide or 6g of sodium hydroxide (corrosive)

10g of glucose (dextrose) 0.05g of methylene blue

50cm<sup>3</sup> of ethanol (highly flammable)

### Method

Before the demonstration make a solution of 0.05g of methylene blue in 50 cm<sup>3</sup> of ethanol (0.1% solution).

Weigh 8g of potassium hydroxide or 6g of sodium hydroxide into a 1dm<sup>3</sup> conical flask. Add 300cm<sup>3</sup> of water and 10g of glucose and swirl until the solids are dissolved. Wear eye protection. Add 5cm<sup>3</sup> of the methylene blue solution. None of the quantities is critical. The resulting blue solution will turn colourless after about one minute. Stopper the flask. This solution is an irritant.

Shake the flask vigorously so that air dissolves in the solution. The colour will change to blue. Place the flask on the top pan balance and observe the mass. The colour will fade back to colourless over about 30 seconds. Observe the mass of the flask and contents again. The more shaking, the longer the blue colour will take to fade. The process can be repeated for over 20 cycles. After some hours, the solution will turn yellow and the colour changes will fail to occur.

A white background is helpful. On a cold day, it may be necessary to warm the solution to 25–30°C or the colour changes will be very slow.

### Health and safety

Ethanol is highly flammable. Extinguish any naked flames.

Potassium hydroxide and sodium hydroxide are corrosive. Wear eye protection (see CLEAPSS Hazcards 40 and 91). Consult your department's risk assessment.

- What practical work is included in your department's scheme of learning to help pupils understand about conservation of mass?
- How could you use these experiments to provide an opportunity in class to teach pupils about the reliability and reproducibility of results?

## Further guidance

The 'blue bottle' experiment: glucose is a reducing agent and in alkaline solution will reduce methylene blue to a colourless form. Shaking the solution admits oxygen which will re-oxidise the methylene blue back to the blue form.

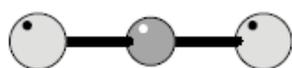
Within the limits of experimental error mass is conserved during these reactions. Because they are closed systems no matter is lost to the surroundings, so we can track the mass of the system before and after the reaction. There are the same numbers of atoms at the end of the reaction as at the start. The atoms have just been rearranged during the reaction.

The activity is adapted from the Royal Society of Chemistry 1995 publication 'Classic chemistry demonstrations'. A class practical based on the vivid colour change in the reaction between potassium iodide and lead nitrate solutions is described on page 152 of the Royal Society of Chemistry 2000 publication 'Classic chemistry experiments'. Both of these publications have previously been supplied free of charge to secondary school science departments and can be found at [www.rsc.org/education/teachers/learnnet/classic\\_exp.htm](http://www.rsc.org/education/teachers/learnnet/classic_exp.htm)

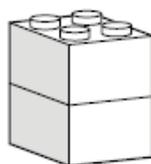
Some possible models to help develop understanding of conservation of matter are:

- molecular models
- plastic bricks
- cards
- computer animations
- drawings
- flicker books.

The first three of these models are the same as those that were used in *Using particle theory to improve understanding of properties of elements and compounds* to represent formation of compounds.



molecular models



plastic bricks



cards

Here they can be used to represent the particles of reactants before a reaction and the products at the end of the reaction.

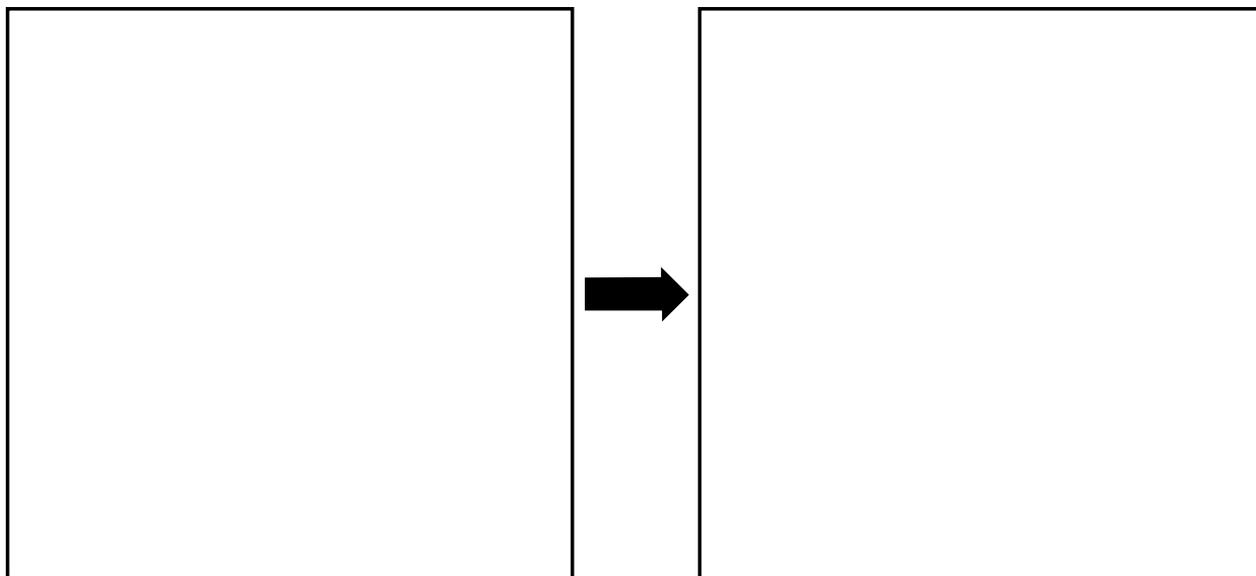
Computer animations will depend upon which software you have available within your department.

The fifth model requires a drawing of the particles of the reactants before the reaction and the products at the end of the reaction.

Draw pictures to represent the particles before and after the chemical reaction.

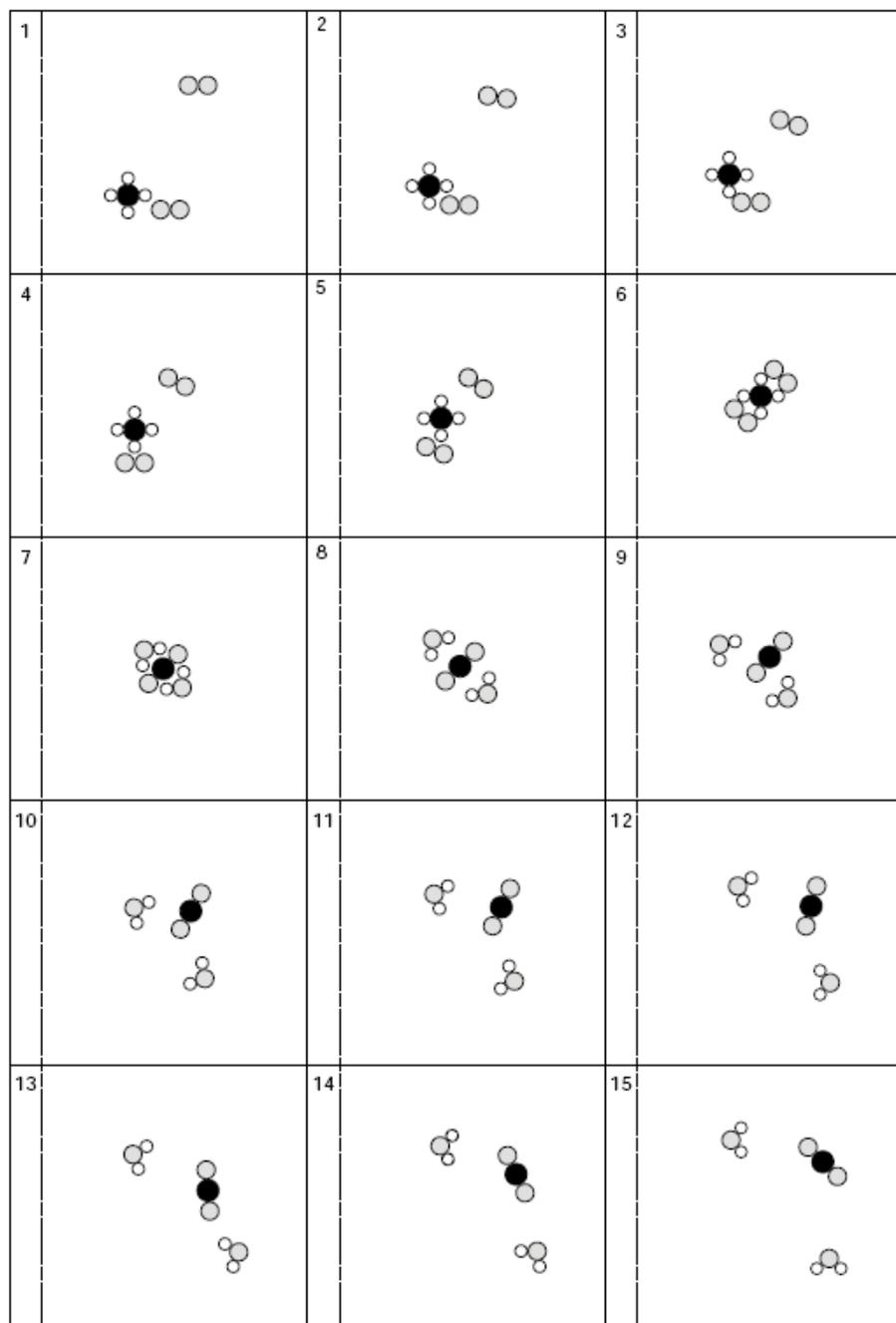
Before

After



The sixth model is a flicker book, to give a crude moving image representation of the rearrangement of the particles during a chemical reaction. Print off a paper or thin card copy, cut it up and staple together to create a flicker book model of the reaction of methane combining with oxygen. You can use the blank flicker book framework to create flicker books for other chemical reactions.

## Flicker book model



These six modelling systems, as well as many others, can also be used to help pupils to:

- understand more about chemical reactions
- realise that these reactions are caused by the rearrangement of particles
- reinforce the idea of conservation of matter during reactions
- begin to name some of the products of reactions
- write simple word equations
- pave the way for writing symbol equations later in pupils' education.

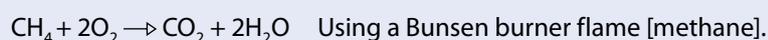
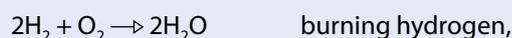
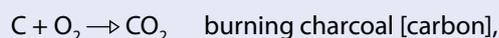
Using only one model to teach about chemical reactions is likely to be too limiting. It will be to pupils' advantage to encounter a range of models and analogies over a period of time.

## Task 13: Evaluating the models

Work with a colleague. Individually consider how well each of the six models can be used to support the teaching and pupils' learning of:

- conservation of matter
- rearrangement of particles
- writing equations
- naming compounds formed.

Now use the model(s) to represent one or more of these reactions:



Share and discuss your ideas with your colleague.

## Reflection

As pupils progress into Year 10 they will usually study displacement reactions between metals and solutions of salts. A more sophisticated particle model is needed.

- How does the particle model need to change to help explain displacement?
- Are the illustrations used in text books helpful or could they cause confusion?
- Can this model be used to represent atoms and ions?

Displacement occurs where a more reactive metal is added to a solution containing a salt of a less reactive metal. The more reactive metal tends to dissolve, forming a solution of its own salt, and the less reactive metal is 'pushed' out of the salt solution to appear as grains of the metal.

This can be demonstrated to pupils using the reaction between copper and very dilute silver nitrate solution. It can be shown effectively to a class by using a digital microscope linked to a computer with the associated software and a data projector. In 2002 the Department for Education and Skills' 'Year of Science' initiative provided all secondary schools in England with an Intel digital microscope. The reaction is also available as a movie clip.

**Practical tip** It is important to rehearse this small-scale displacement reaction using the microscope before demonstrating it in the classroom with pupils.

Use a single piece of copper foil about 0.5cm long on a small watch-glass. Add about 2cm<sup>3</sup> of 0.05mol dm<sup>-3</sup> silver nitrate solution; the concentration is not critical and a more dilute solution will give you more time to manoeuvre the reactants and equipment.

Setting up and manoeuvring the copper foil so that the edge of the foil is in the field of view is best done at x60 magnification, rather than x200. Keeping the growing crystals of silver in focus can be a little tricky. It is helpful to have previously recorded a sequence of crystal growth at x200 magnification on time lapse so that you have a good-quality sequence ready to show.

The appearance of attractive crystals of silver can be seen as the product of the reaction.

0.05mol dm<sup>-3</sup> silver nitrate solution is low hazard but will stain clothes and skin. Wear eye protection when using silver nitrate solution. See CLEAPSS Hazcard 87.

Displacement reactions can also be demonstrated by:

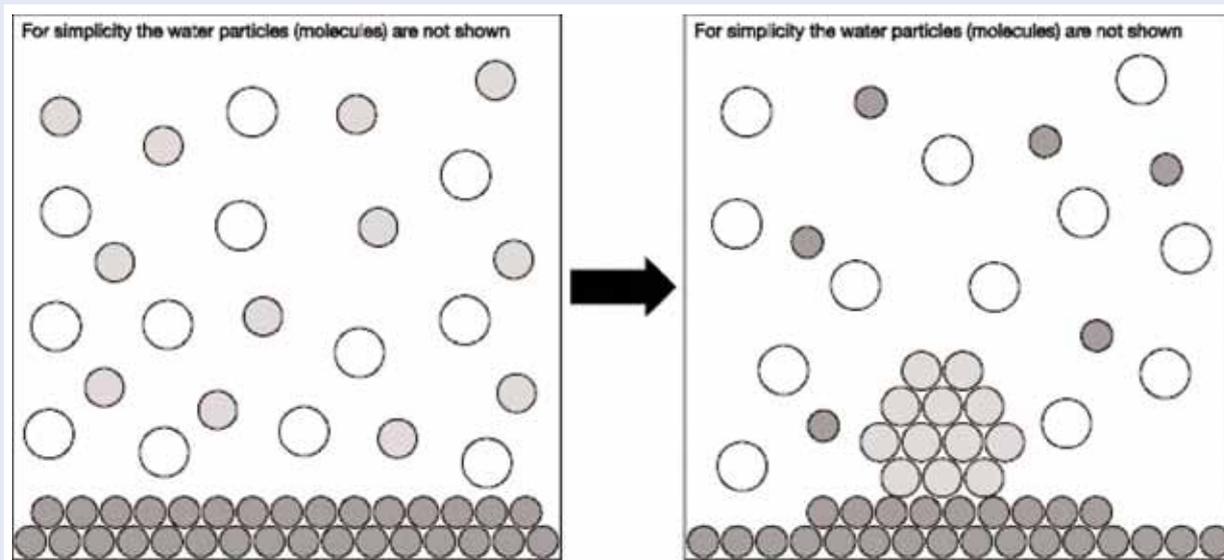
- placing a strip of zinc foil into a test-tube of lead nitrate solution
- placing a strip of iron or steel into a test-tube of copper sulphate solution
- suspending a coil of copper wire in a test-tube of silver nitrate solution.

The suspended crystals that are produced will collapse if jolted, so they will not survive being passed round a class.

## Task 14: Modelling displacement reactions

Try the displacement reaction above for yourself or refer to the time lapse video of silver crystals growing, made using this method.

- Write the formula for the reaction.
- Identify the particles on the diagram below.
- Annotate the diagram to explain what is happening.



If you would like to see what other teachers thought please refer to the Answers section.

## Further guidance

A number of simplifications and assumptions have been made in this task and the diagrams, such as:

- the water molecules have been ignored in the drawings because they remain unchanged by the reaction and can be omitted for convenience
- nitrate particles (ions) are represented by circles, as are the other particles
- early on it would be acceptable for most pupils to use the name copper nitrate rather than copper(II) nitrate
- no distinction has been made here between atoms and ions, but this would be done when ions are more explicitly taught during Key Stage 4
- the reasons why copper is more reactive than silver and why one copper atom can displace two silver atoms have not been explained. These explanations require a more sophisticated model of the atom which involves the arrangement of electrons within the atom.

## Resources

These resources have been referred to, or used in the preparation, of this study guide. You may find it helpful to refer to some of these in order to continue with aspects of your development in this topic.

Author	Title	Year of publication	Publisher	ISBN, reference number or website
DCSF/ National Strategies	Science Framework	2008	DCSF	<a href="http://www.standards.dcsf.gov.uk/nationalstrategies">www.standards.dcsf.gov.uk/nationalstrategies</a>
QCA	Science: a scheme of work for Key Stage 3	2000	DfES/QCA	1 85838 382 X
Taber, K.	Chemical misconceptions – prevention, diagnosis and cure: vols 1 and 2	2002	Royal Society of Chemistry (RSC)	0 85404 386 1 0 85404 381 0
Lister, T.	Classic chemistry demonstrations	1995	RSC	1 870 343 38 7
Hutchings, K.	Classic chemistry experiments	2000	RSC	0 85404 919 3
Warren, D	Chemists in a social and historical context	2001	RSC	0 85404 380 2
CLEAPSS	Hazcards	2000	CLEAPSS	
CLEAPSS	Laboratory handbook	2001	CLEAPSS	
CLEAPSS	Guide L195 Safer chemicals, safer reactions	2003	CLEAPSS	
McDuell, B.	Teaching secondary chemistry	1999	ASE/John Murray	0 71957 638 5
Sang, D.	Teaching secondary physics	1999	ASE/John Murray	0 71957 636 9
Wilson, E.	Teaching chemistry to KS4	1999	Hodder and Stoughton	0 340 73764 6

CLEAPSS publications are available to schools in local authorities that subscribe to CLEAPSS.

A copy of the Royal Society of Chemistry (RSC) publications has previously been supplied free of charge to secondary school science departments. Details of availability can be found on the RSC website.

## Bringing it all together

In this unit there have been a number of tasks and suggestions for you to pair with another teacher or to work individually while you develop your confidence in teaching about particles. Here are some suggested next steps you may care to take:

- Check that you start teaching about particles early in Year 7.
- Identify lessons where pupils can apply the particle model.
- Use the four-stage method whenever a new model is introduced.
- Use Concept Cartoons™ to discover Year 7 pupils' ideas about Brownian motion.
- Ask pupils to suggest strengths and limitations whenever using particle models.
- Use some of the questions after Task 6 to engage and challenge pupils.
- Apply ideas of particles when teaching digestion.
- Teach the development of ideas and evidence about particles.
- Review the practical work used to illustrate formation of compounds.
- Use a variety of models when teaching about chemical reactions, equations and formulae.
- Try out the teaching sequence suggested in Modelling matter: the nature of bonding Interactive teaching (go to [www.standards.dcsf.gov.uk/nationalstrategies](http://www.standards.dcsf.gov.uk/nationalstrategies) and search for the term 00094-2008).
- Develop a better understanding of models by reading Using Models study guide also from Interactive teaching (go to [www.standards.dcsf.gov.uk/nationalstrategies](http://www.standards.dcsf.gov.uk/nationalstrategies) and search for the term 00094-2008).
- Use tasks that help identify pupils' understanding and misconceptions about particles (e.g. concept maps and Concept Cartoons™).
- Use one of the demonstrations to illustrate conservation of mass and developing equations.
- Continue your development by consulting some of the references given.

Here are some further general pointers in order to help you take this work forward:

- Start small: choose one class to work with. Year 7 would be a good choice because there is the excitement of meeting ideas of particles to explain physical and chemical change. For the first time however, if you have another class you feel would respond well to this, then use them.
- Ask another teacher, a chemistry specialist or your science consultant to help you. Technicians and teaching assistants can be very useful in helping you to demonstrate a model or a procedure while you explain to the pupils what is happening.
- Ask for some protected time before the lesson so that you can check the resources and procedures and practise your script.
- Make sure your line manager or head of department/subject leader knows what you are doing. This will enable dissemination to happen much more easily.
- Share the class with another teacher, so that you can take responsibility for the part of the lesson where the particular approach to teaching about particles is used.
- Ask your science consultant to team-teach the lesson with you. You should each take responsibility for a part of the lesson where particle ideas are taught and then jointly review the outcomes after the lesson.