ON THE BALL

SOUTHAMPTON CITY COUNCIL

University of Southampton

PARTICLE MODELS
FOR KEY STAGE 3 SCIENCE

ON THE BALL
Particle models for KS3 Science

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Particle models *for* KS3 Science

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Models – a strategy for learning science

Science is about explanation. It attempts to make sense of the world by constructing models or theories through a creative approach, often referred to as the hypothetico-deductive method. These models or theories are VISUALISATIONS; they are pictures we carry in our heads, often brought about by concrete representations.

What are models ?

A model is a representation of an object, event or idea. This representation creates a vehicle through which the object, event or idea can be conceptualised and understood.

Models are important in science teaching, as major tools for teaching and learning. They are more than this, however. Models are one of the main products of science – the progress of science is normally marked by the production of a series of models, each associated with a distinctive theory. Modelling is a major element in scientific methodology (Gilbert, 1994).

Models can be of a number of different types (Gilbert, 1998):

***Mental* model** – that each of us visualise in our mind;

***Expressed* model** – when we try to explain or present in another form our mental model;

***Consensus or scientific* model –** an expressed model which has gained acceptance within the scientific community;

***Historical* model** – a *consensus* model which has been superseded at the 'cutting edge' of science e.g. the 'plum pudding' model of an atom is an historical model which was superseded by 'orbiting electrons' model.

A ***teaching* model** is one specifically produced to teach a *consensus* or *historical* model. This is something that can help pupils grasp the idea and help visualise the idea, for instance using the ball bearing 3D model for the kinetic theory. An analogy can also be a teaching model, such as the water flow model to represent current.

Models to teach Key ideas at Key stage 3.

What has to be taught at Key Stage 3 should not be regarded as simply content all of equal worth. Rather there are some ideas which are key. Understanding these key ideas well and being able to apply them to explain and understand new phenomena and events makes learning effective. We must not lose sight of the wood for the trees.

Principles:

- There are some key ideas in science an understanding of which helps development in other areas.

- Some of these are abstract explanatory theories, e.g. particle theory helps explain the changes and interactions between matter.
- When these ideas are introduced it is more effective if pupils are provided with clear visual models which make the ideas concrete (teaching models)
- These ideas network together and impinge on each other. The order in which we teach them will have an effect on how well pupils develop their understanding.
- Early introduction to these key ideas will provide more opportunity to develop understanding
- Understanding of these ideas deepens and further develops from constantly attempting to explain new phenomena using these key scientific ideas.
- As attempts to explain new phenomena increase, there will come a time for some phenomena when the accepted scientific idea will not be good enough. At this point the scientific idea will need to increase in sophistication to explain the new phenomena.

What ideas in Chemistry are important at Key Stage 3?

What has to be taught at Key stage 3 is arranged in the programme of study under a series of themes:
Materials and their properties
Classifying materials
Changing materials
Patterns of behaviour

A fundamental idea embedded in these areas is that of PARTICLES.

Teaching Strategy

In order for pupils to grasp ideas, such as particles, well they need to:

a. be introduced to them in Year 7

b. be introduced to them through the use of clear teaching models

c. have the chance to practice using the idea to explain new situations (apply) and if need be increase the sophistication of the teaching model to explain new situations

Recommendations for practice

Research evidence suggests the following as being effective in helping pupils understand chemical concepts and models as an important aspect of developing and explaining ideas:

- Use models at the beginning of a topic (Sizmur & Ashby, 1997) or integrated fully into the teaching of key ideas.
- Where analogies are used, check pupils' understanding of the analogy itself before using it to explain the key idea.
- Show the similarities and differences of the model to the target idea – i.e. highlight the strengths and limitations of the model.
- Give pupils practice in developing their own models and use them to explain ideas. Highlight the strengths and limitations of their models
- Encourage pupils to explore the use of (their) models in explaining related ideas – does the model still hold?
- When using concrete models (e.g. drawings/ 3D models of atoms, bonding etc), 3D models seem to lead to greater understanding and retention of key ideas compared to 2D.
- Enjoy using models – they provide an interesting, visual and stimulating way of understanding chemical ideas! Models can really help and motivate low achieving pupils.

Suggested Teaching strategy:

Step 1 Teach the model, making sure pupils understand it and that they can 'picture' it.

Step 2 Show pupils how the model can be used to explain certain phenomena and the limitations of the model

Step 3 Practice using the model e.g. introduce a new phenomenon and ask pupils to use the model to explain it

Step 4 Challenge the model - perhaps through an investigation. Encourage pupils to see the limitations of the model by asking them to explain new phenomena which cannot be explained with the model

Step 5 Teach a more sophisticated model as appropriate and return to step 1

How to use this resource

This resource contains examples of models which can be used in conjunction with teaching KS3 Materials and their properties. The underlying consensus model is that of particle theory.

Each page has common features as shown:

A clear **National Curriculum Reference** to the exemplar QCA scheme of work. The following units are covered in this pack:
7F Simple chemical reactions
7G Particle model of solids, liquids and gases
7H Solutions
8I Heating and Cooling
8E Atoms and Elements
8F Compounds and mixtures
9E Reactions of metals and metal compounds
9F Patterns of reactivity
9H Using Chemistry

Consensus model – This shows a representation of the accepted scientific model. It is this model we are trying to help pupils understand as an aid towards developing understanding of key concepts.

This is done through:

- Showing the strengths and weaknesses of appropriate **Concrete models**;
- Allowing **Student ideas** about the models to be explored fully, so that students have a clear opportunity to articulate their understanding in relation to the consensus model;
- Showing or carrying out **Observations** which relate the models to examples of the concept in practice;
- Evaluating the strengths and weaknesses of the particular **Consensus model** itself.

Suggestions for **Student activities** and **key questions** are included. KS3 'student speak' answers to questions are shown, recognising that these are not always full scientific answers. They are intended to encourage explanations in terms of particles.

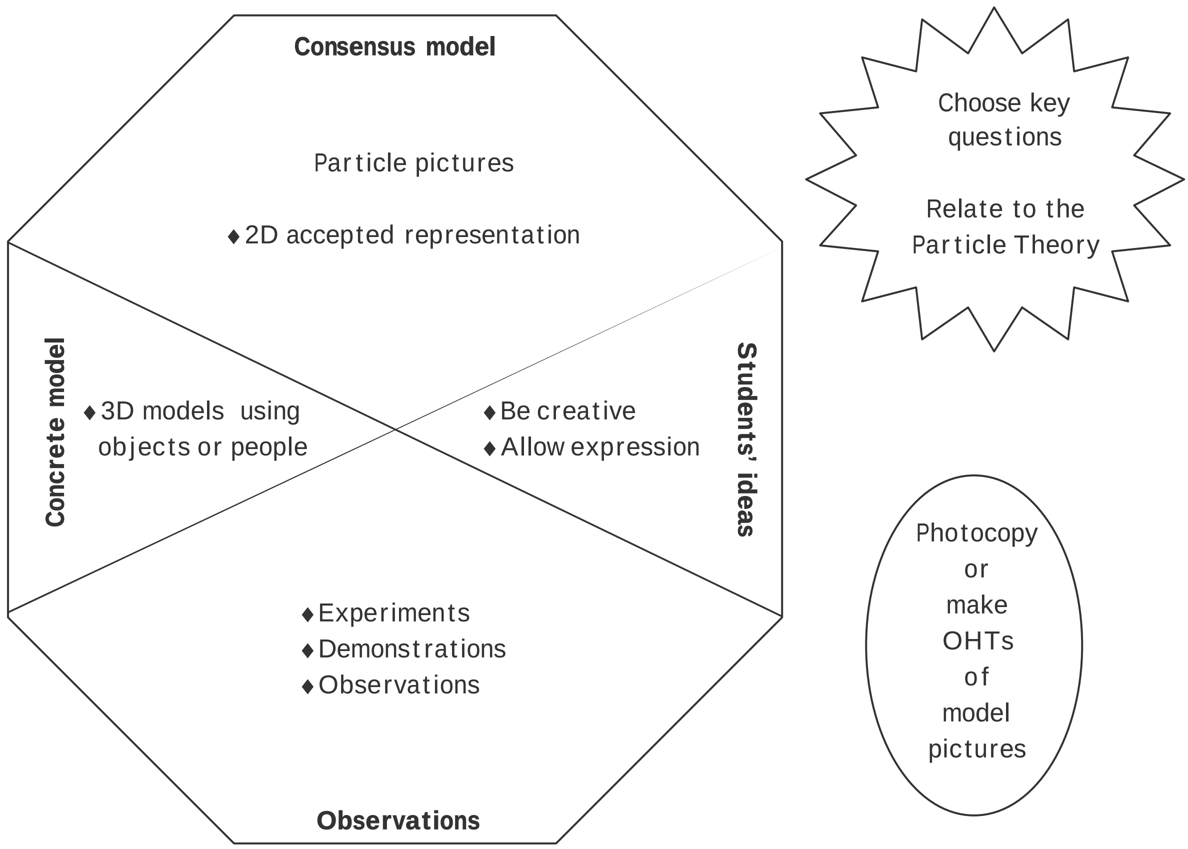
It is important that **Student evaluation** encourages you and the students to examine the good and bad features of the model in aiding their understanding of the key concept.

Drawings of models follow relevant pages. These are intended to be used as OHTs to illustrate the model and highlight its strengths and weaknesses.

Guidance for teachers

National Curriculum Reference : Title

National Curriculum learning objectives
- See Scheme of Work in left hand column



Student Activities

- Observe the experiments
- Explain the process – in terms of particles, using models
- Be the model – act out the arrangement/movement of the particles
- Devise your own model – it's like….. – allow students to be imaginative

Student Evaluation – any model has good and bad features

In what ways is the model good at helping you understand about particles?

Think of good features with your students –what can it explain? It can clarify misconceptions

In what ways is the model not good at helping you understand about particles?

Think of poor features –what can it not explain? It generates discussion.

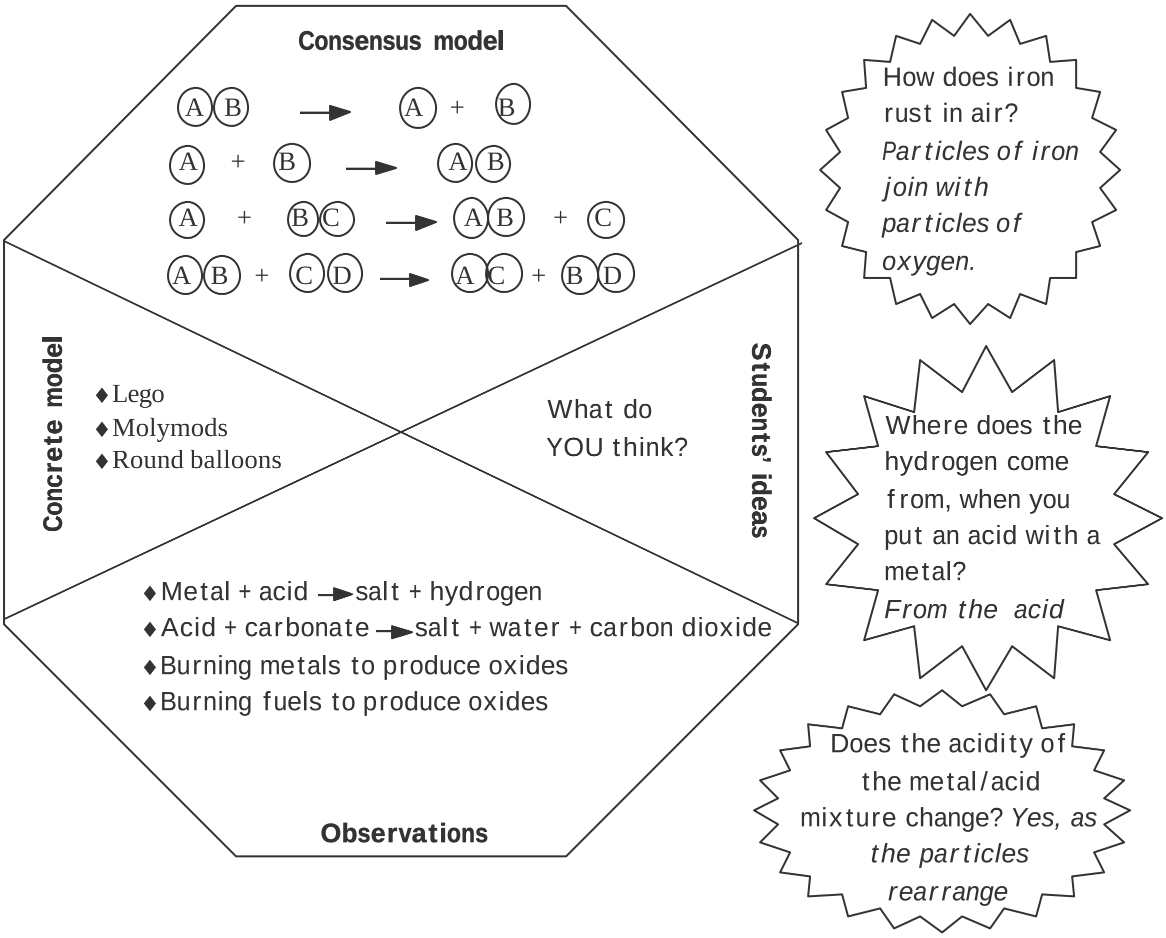
Using models and analogies in the teaching of chemistry at KS3: Unit 7F Simple chemical reactions

<table>
<tr><th>Key concepts</th><th>Phenomena that can be explained</th><th>“Visualisations” - Concrete models or analogies used by teachers</th></tr>
<tr><td>• When substances react they form new substances in predictable ways
• Products in a chemical reaction are a result of recombination of particles, showing you cannot create something form nothing
• Some reacting particles may come from unexpected places e.g. air
• All acids contain particles of hydrogen
• Burning is result of oxygen particles reacting with particles in the “fuel”
• All carbonates react with acids to form CO_2 because carbonates contain particles of C and O</td><td>• Acids react with metals to give off hydrogen
• Acids react with carbonates to emit CO_2
• Burning results in the formation of oxides</td><td>• Use LEGO bricks or poppet beads to show the 3 or 4 possible combinations
• Black single cube Lego bricks can be used to represent the hydrogen in an acid</td></tr>
<tr><td colspan="3">Commentary: In this unit of the exemplar QCA scheme of work there is no attempt to provide models of chemical reactions using the particle theory. This is left to later. However provided this unit is taught after 7G and 7H, using Lego bricks, Molymod, or beads can help establish ideas about chemical reactions and help prevent misconceptions later. Helping pupils see that chemical reactions are essentially rearrangements of particles can help demystify chemistry and lead to an understanding that there is a reason for systematic naming of chemical compounds. Establishing that there are 3 possible types of chemical reaction (or 4 if you consider that A + BC→ AB +C is not a subset of AB+CD→ AC +BD) is very helpful in rooting the idea chemical reactions occur in predictable ways. Encourage pupils to model chemical reactions as they take place using beads or Lego bricks. Encourage them to name the compounds formed and see show how this relates to the particles present.</td></tr>
</table>

7F Simple Chemical Reactions : Chemical change

National Curriculum learning objectives

- Some new materials are formed during a chemical reaction
- Products of a reaction can (sometimes) be deduced from the reactants



Student Activities

- Observe the experiments – totally new substances formed
- Explain the process – new substances are a result of a rearrangement of the particles in the starting chemicals
- Be the model – act out the model, changing partners
- Devise your own model

Student Evaluation

e.g. In the consensus model

In what ways is the model good at helping you understand about particles?

It shows that you only create something from what already exists

In what ways is the model not good at helping you understand about particles?

It doesn't always help you predict which reactants will recombine

AB + CD ↛ AD + BC

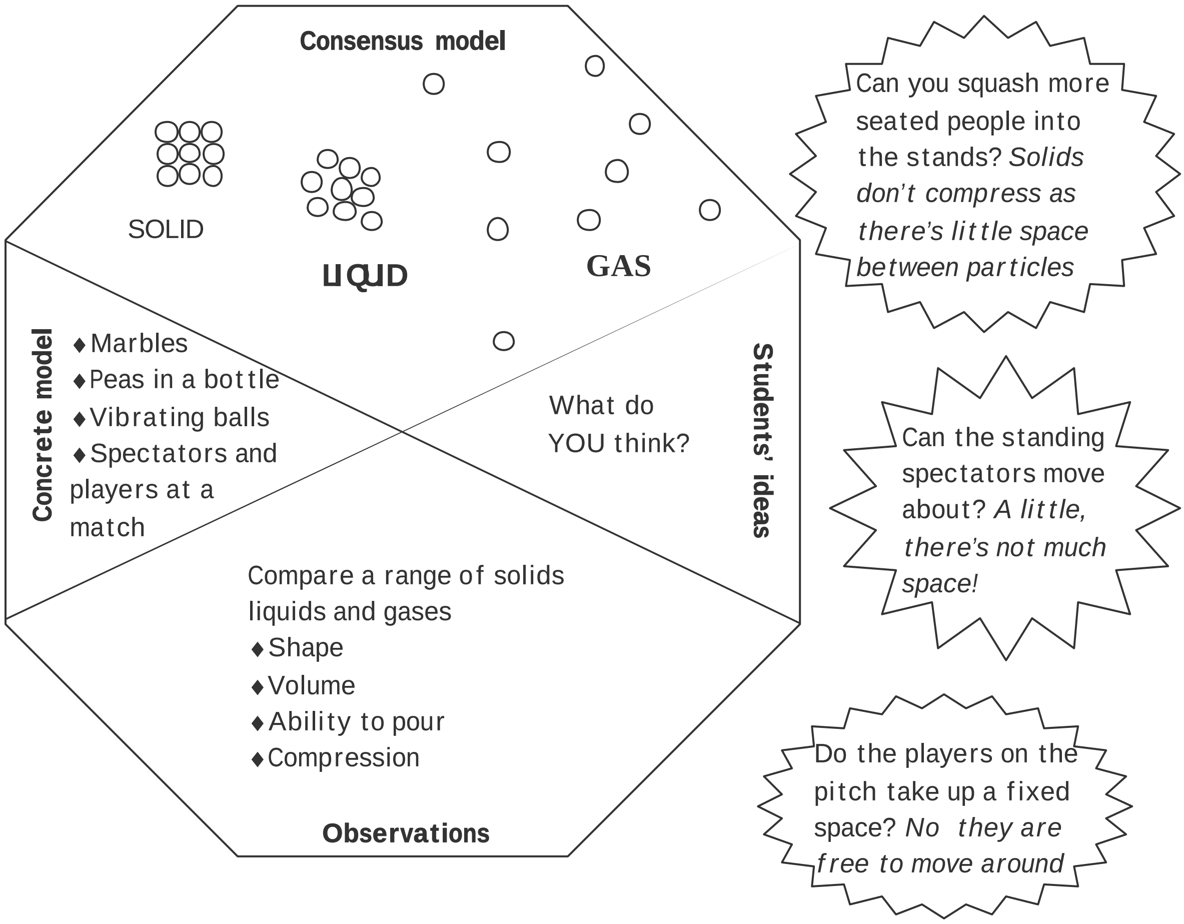
Using models and analogies in the teaching of chemistry at KS3: Unit 7G Particle model of solids, liquids and gases

Key concepts	Phenomena that can be explained	"Visualisations" - Concrete models or analogies used by teachers
• Matter is composed of discrete particles • Particles have kinetic energy and are in constant motion • Particles in a solid vibrate about a fixed position and are relatively close together • Particles in a liquid move more freely and are still relatively close together • Particles in a gas are moving freely and are far apart • Transferring more energy to a solid, liquid or gas by heating causes the particles to move faster ("vibrate") and further apart • Particles are similar in size and their sizes do not change when the substance is heated • There are forces of attraction holding particles together in a solid and liquid	• Mixing (diffusion) of liquids and gases • The volume of a liquid resulting from the melting of a solid is about the same • When either solid, liquid or gas is heated it expands • Pressure exerted by a gas on walls of a container • A previously heated can filled with air collapses when a lid is placed on and allowed to cool • Solids and liquids cannot easily be compressed • Less energy is needed to change a solid to liquid than liquid to gas *(In this unit the phenomena are used to generate evidence for the existence of particles)*	• Particles can be thought of as the same type and to be small "hard" spheres e.g. marbles • Different types of seeds, marbles can show idea of diffusion • Marbles bouncing on a balance can show pressure • 3D kinetic model used to show particles in 3 different states, similarities and differences in volumes and gas pressure • 3D kinetic model shows consequence of transferring more energy to the system by increasing speed of motor (analogy to heating) – increased movement, expansion and increased pressure (for gas) • Animation clips from CD-ROM or video can show difference in proximity and movement of particles of different states of matter, expansion and collapsing can phenomena • People/pupils as particles e.g. spectators and dancers at a carnival or themselves as different states or simulating expansion
Commentary: Pupils readily take to the idea that matter consists of particles; indeed many will have come across the idea in their primary schools although this is not part of the programme of study for KS2. Encourage pupils to think of the particulate nature of matter as a model and that it helps us explain observations. Take care when comparing states to make the particles in a solid and liquid to appear similar in distances apart. This explains similarity in volume when solids melt to form liquids (not water). Be aware some exam boards and test mark schemes require a proportion of particles to be "touching" in a liquid. When using a model to explain expansion in solid, particles can be considered to vibrate with a bigger amplitude about a fixed position, so taking up more space. It has been a common misconception that the particles themselves expand when heated. This should be checked by questioning and corrected. Pupils should be made aware of the strengths and limitations of models (e.g. compare view of expansion and similar volume on melting, i.e. "touching particles" or not). This helps them understand that the theory is itself a model.		

7G Particle Model of solids, liquids and gases

National Curriculum learning objectives

- Generate descriptions of solids liquids and gases consistent with the evidence and their scientific knowledge e.g. a solid is made of tiny grains glued together.
- Describe in writing and drawing the arrangement, proximity and motion of particles in solids, liquids and gases



Student Activities

- Observe the experiments – notice how solids, liquids and gases behave differently- look at football match picture – use vibrating balls
- Make the model – put seeds in a plastic bottle
- Be the model – act out movement/spatial arrangement of particles
- Devise your own model – it's like…….

Student Evaluation

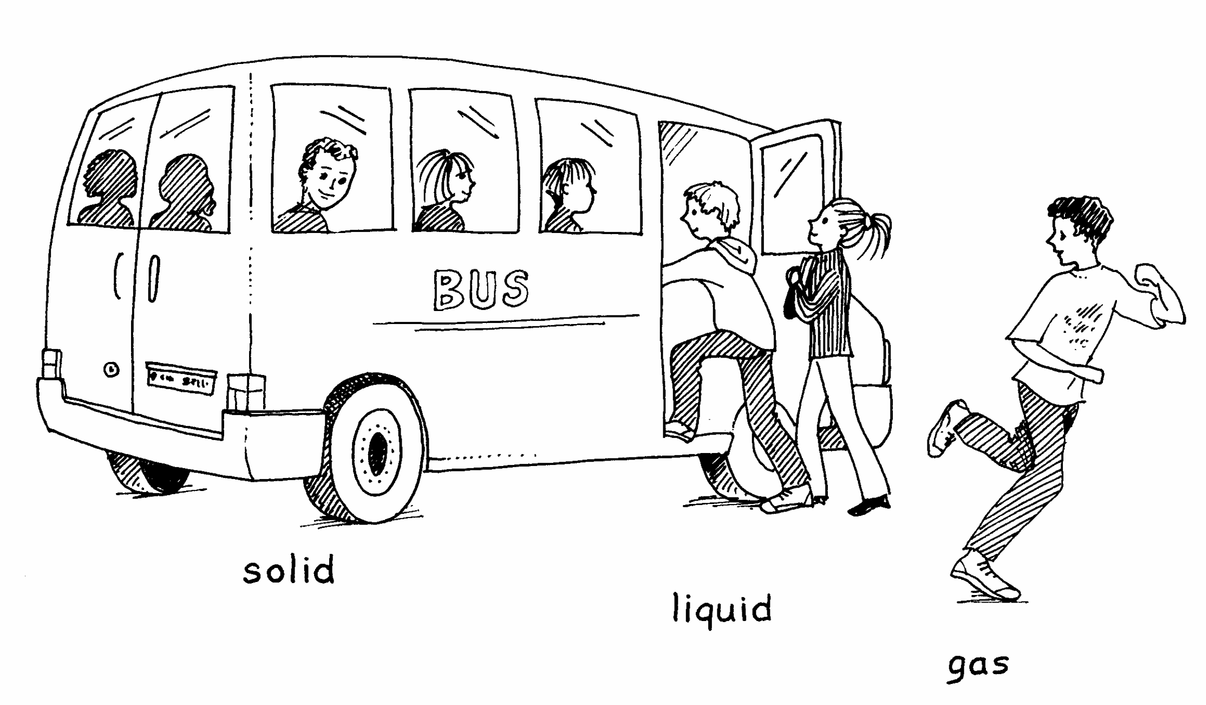
e.g. Spectators and players at a match

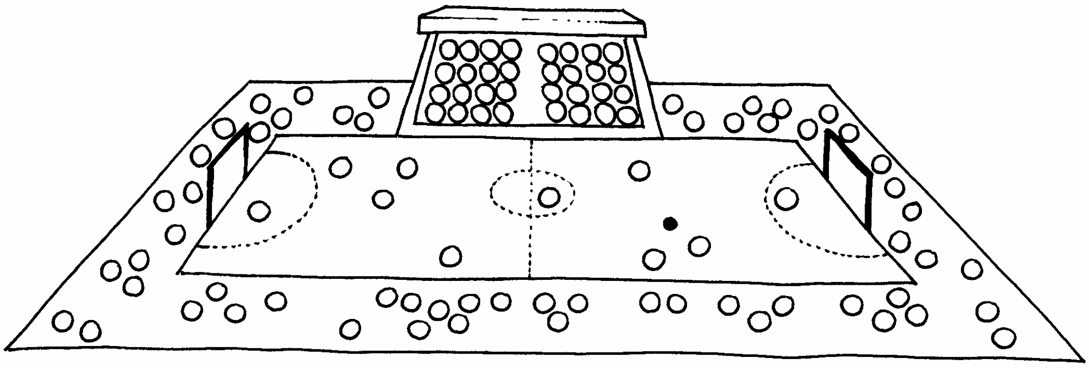
In what ways is the model good at helping you understand about particles?

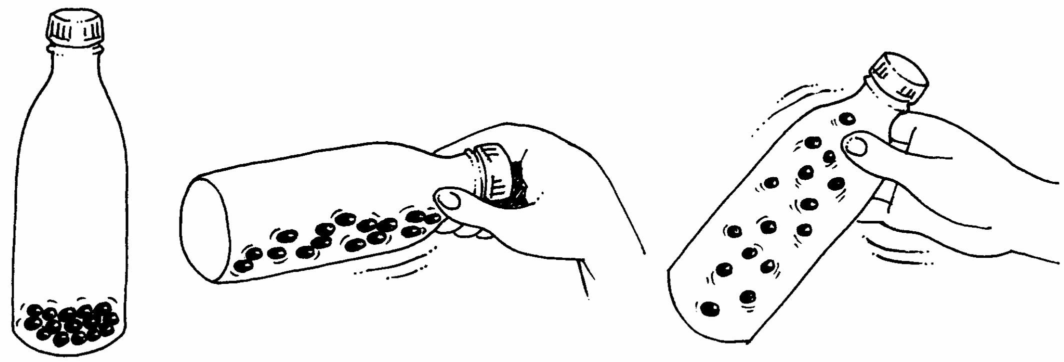
It helps you 'see' the very small

In what ways is the model not good at helping you understand about particles?

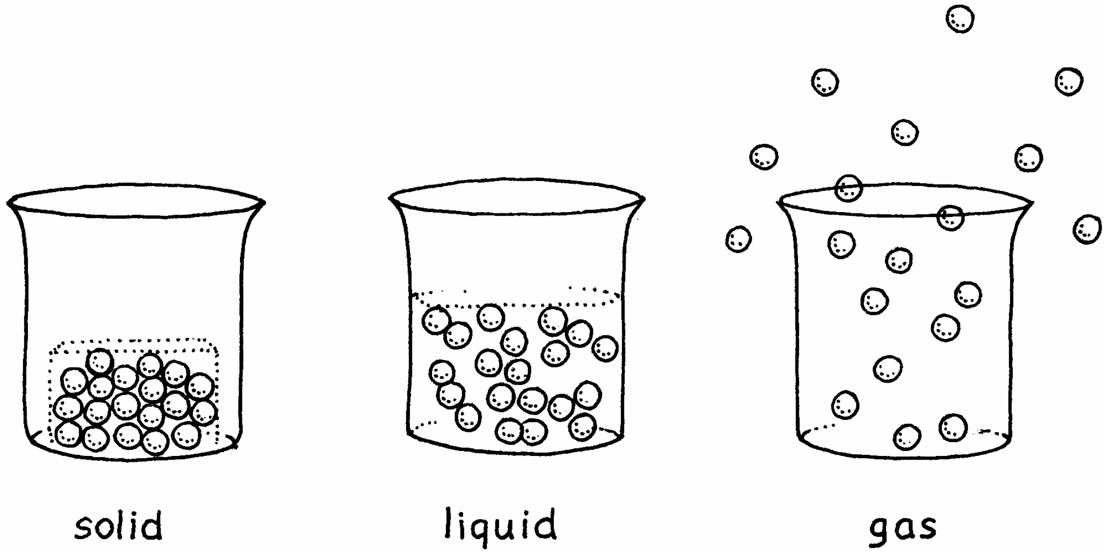
Particles are not living things


BUS
solid
liquid
gas





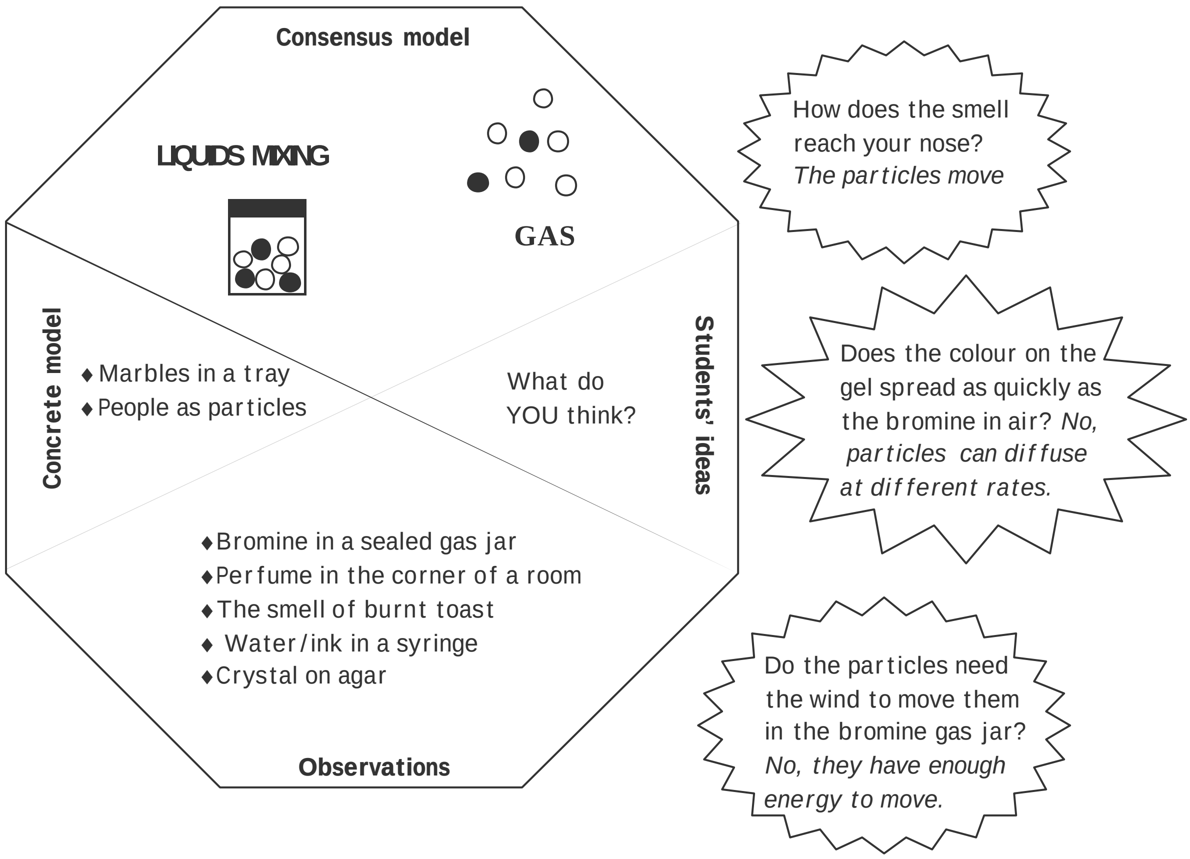
solid liquid gas


solid
liquid
gas

7G Solids liquids and gases – The Particle Model : Diffusion and mixing

National Curriculum learning objectives

- Describe how the particle theory can explain some phenomena e.g. diffusion of gases, mixing of liquids
- Explain observations in terms of particles



Student Activities

- Observe the experiments – look at bromine/agar – smell the perfume
- Explain the process – use the idea of moving particles
- Be the model – act out the movement which leads to mixing of particles
- Devise your own model – it's like ....

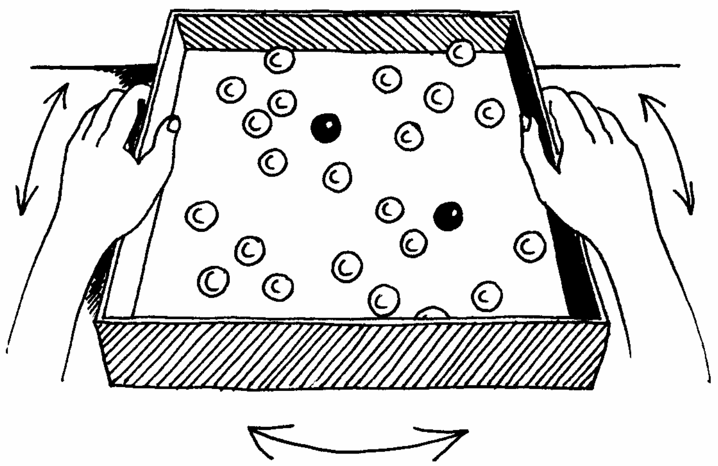
<u>Student Evaluation</u> e.g. In the marbles in a tray

In what ways is the model good at helping you understand about particles?

It helps you 'see' very small scale movements

In what ways is the model not good at helping you understand about particles?

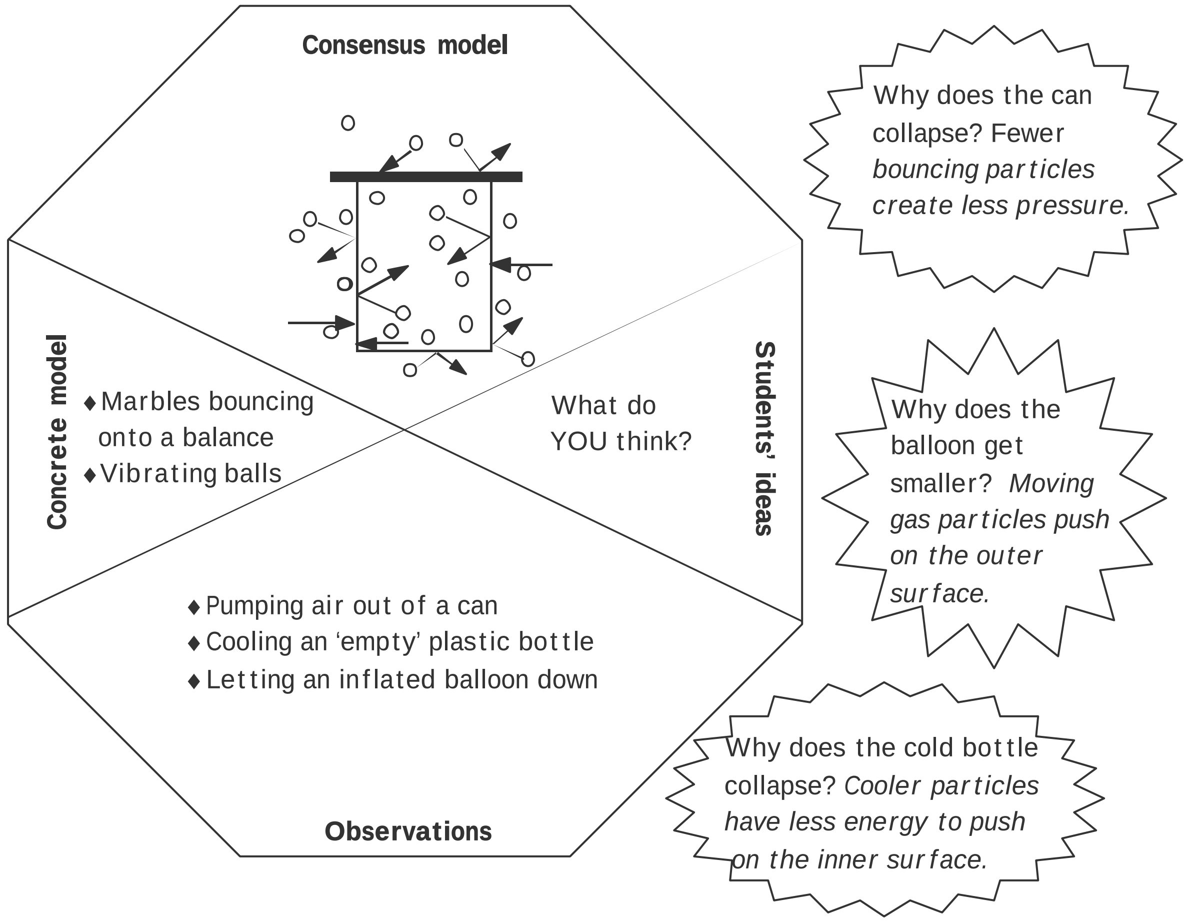
The energy really comes from heat – not shaking the tray



7G Solids, liquids and gases – The Particle Model : Pressure

National Curriculum learning objectives

- ♦ That gas particles are moving around all the time
- ♦ That gas pressure is caused by particles hitting the walls of the container



Student Activities

- ♦ Observe the experiments - Look at the collapsing can and blowing up a balloon
- ♦ Explain the process – what do you notice about using the idea of moving particles
- ♦ Be the model – act out movement which leads to causing pressure/ differences in pressure
- ♦ Devise your own model – it's like.....

Student Evaluation

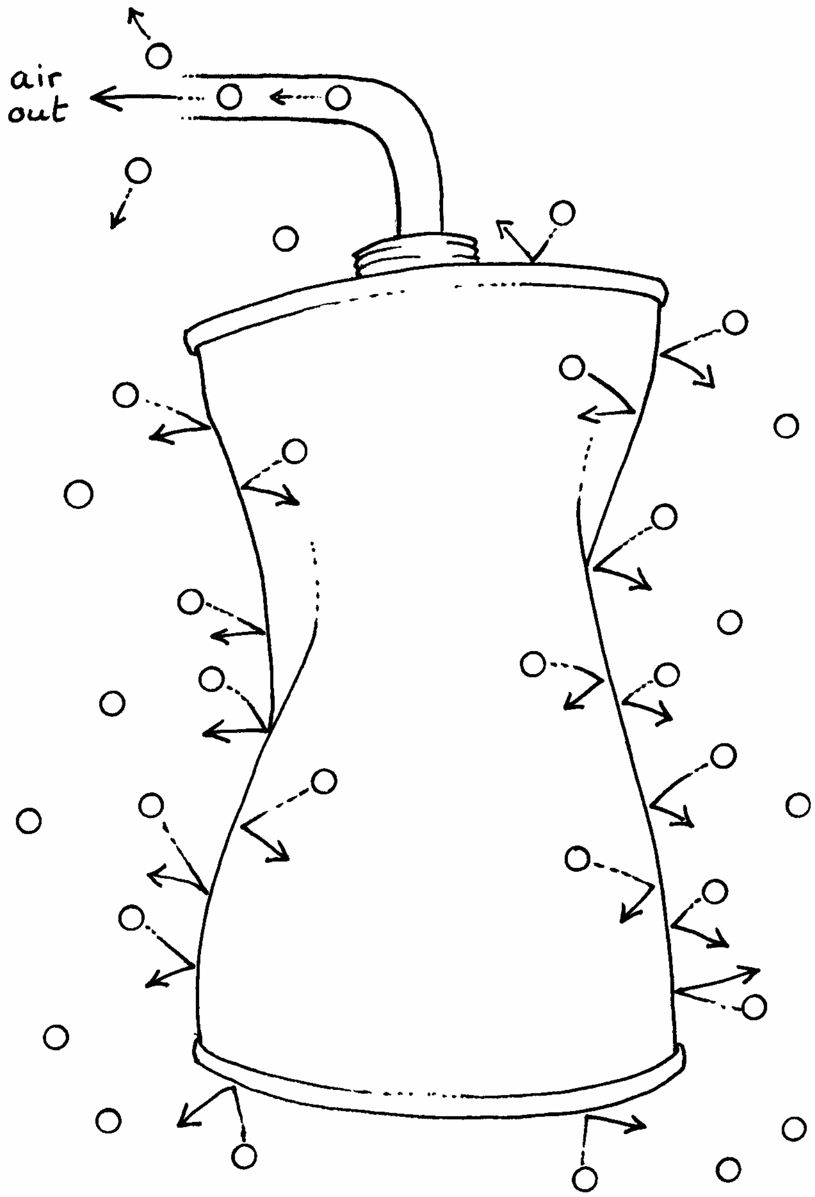
e.g. The marbles in the balance

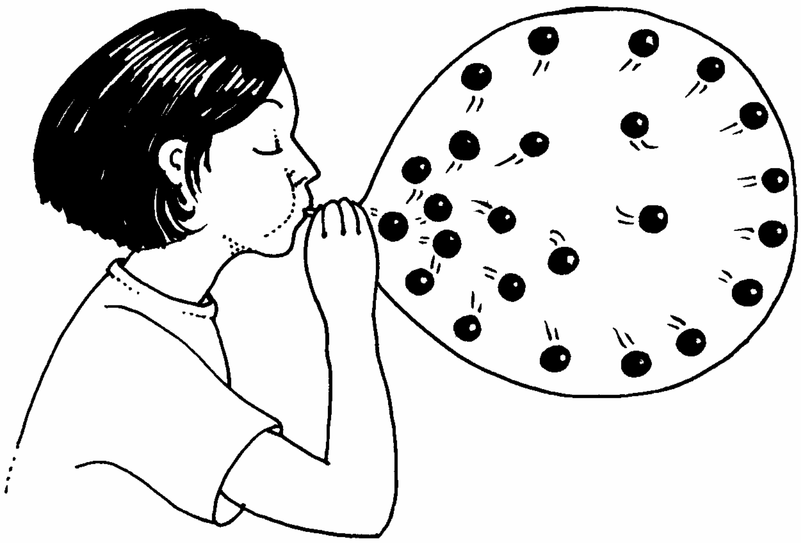
In what ways is the model good at helping you understand about particles?

It helps you 'see' how bouncing particles cause pressure

In what ways is the model not good at helping you understand about particles?

Difficult to show random collisions


air
out



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Using models and analogies in the teaching of chemistry at KS3: 7H Solutions

Key concepts	**Phenomena that can be explained**	**"Visualisations" - Concrete models or analogies used by teachers**
• Matter is composed of different types of particles because substances behave differently • Dissolving is mixing and as one substance dissolves in another their particles mix. • Solutes dissolve in solvents to different extents • Mass is conserved when dissolving takes place because total number of particles is the same • Particles are so small that they cannot be seen, this is why substances appear to disappear when dissolving and solutions cannot be separated with a filter paper • Groups of particles must be held together in different ways because not all combinations dissolve and some dissolve more easily • Particles of different substances can be of different sizes • Hotter substances have more chance of mixing because their particles are moving faster with more energy	• When substances dissolve in a liquid they appear to disappear • The mass of the solution is the sum of masses of solute and solvent • Most substances dissolve more easily in hotter liquids • Filtering cannot separate solutions • Chromatography (which relies on the extent to which substances dissolve) separates materials • When ethanol is mixed with an equal quantity of water there is an overall reduction in volume	• mixing different beads or peas and barley/rice in a container to show dissolving • mixing of peas and barley (or beads of different size can be a good enough model at this stage to show why ethanol and water show overall reduction in volume when mixed (smaller particles fit into spaces in the gaps) • Solvents give solutes "piggy back" rides can be used as a simple explanation of chromatography, with some particles being carried further faster • The raft analogy can be used to explain chromatography

Commentary:
Pupils will have had a lot of experience of dissolving sugar and salt in water at different temperatures; but will probably not have been asked to explain dissolving in terms of particles. We need to make the point that dissolving doesn't make particles cease to exist, rather it separates them so we cannot see the substance; "we are looking through the gaps" can be a good enough explanation at this stage. When mixing ethanol with water we see an overall reduction in volume which is unexpected. Explaining this in terms of some particles (ethanol) being much larger, so when they fit together there are spaces that can be filled with smaller particles (water) is a simple model to help explain this. This has been the subject of controversy, but again is a "good enough" explanation at this stage. A raft analogy can be used to explain chromatography, rafts = mixtures, current = solvent, riverbed/stumps cause snags (selective absorption/stationary phase e.g. the filter paper) some rafts get snagged more easily than others

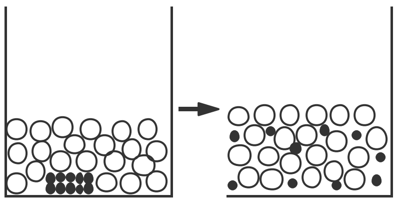
7H Solutions : Dissolving

National Curriculum learning objectives

Use particle model to explain a solid dissolving in water

- ♦ Solute and solvent particles intermingle
- ♦ Mass is conserved

Consensus model



Concrete model

♦ Mixing Molymods or beads

♦ Mix dried peas and rice

Students' ideas

What do YOU think?

Observations

♦ Making a jelly

♦ Dissolving sugar

♦ Dissolving copper sulfate

♦ Dissolving ethanol in water (same mass less volume)

Why does all the jelly turn red? *The particles mix.*

Why does $50cm^3$ of ethanol + $50cm^3$ of water = $96cm^3$ of solution? *Some spaces between the particles are filled*

How would you know that none of the particles were lost? *The total mass remains the same.*

Student Activities

- ♦ Observe the experiments – make a jelly – dissolve salt in water – mix ethanol and water
- ♦ Explain the process – use the idea of mixing particles
- ♦ Be the model – act out the movement which leads to the mixing of particles
- ♦ Devise your own model – its like ....

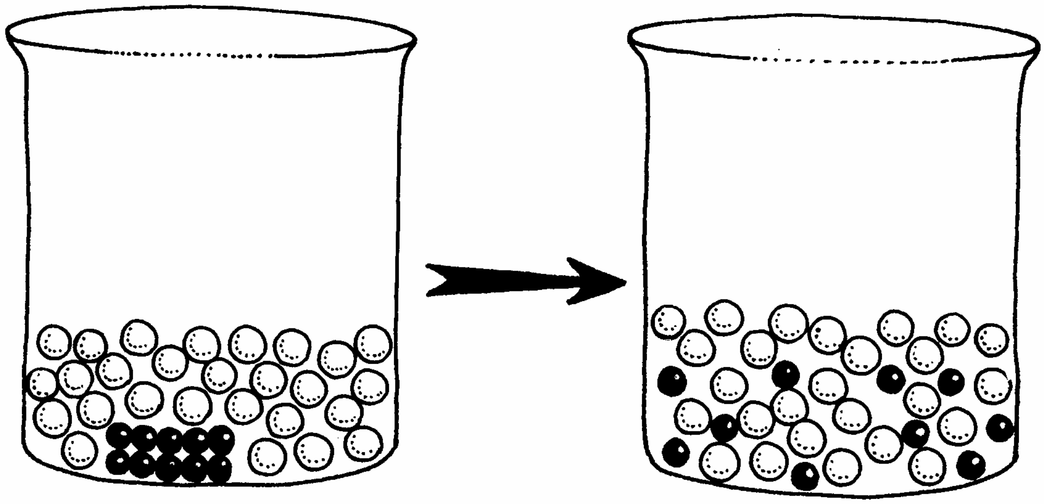
<u>Student Evaluation</u> e.g. Mixing beads

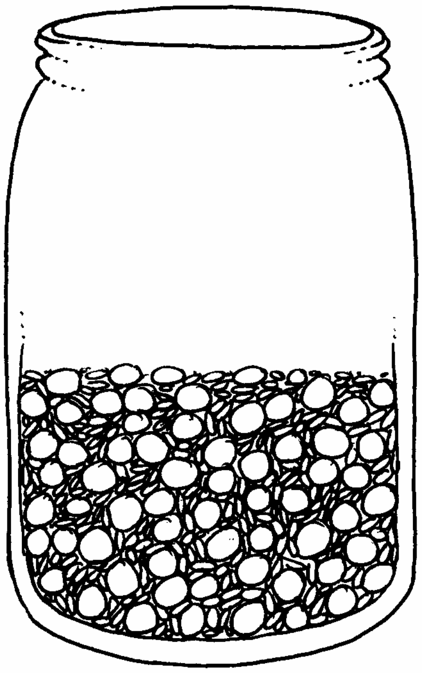
In what ways is the model good at helping you understand about particles?

It helps you 'see' that the particles intermingle

In what ways is the model not good at helping you understand about particles?

It does not explain why some things are NOT soluble.





Using models and analogies in the teaching of chemistry at KS3: Unit 8I Heating and Cooling

Key concepts	Phenomena that can be explained	"Visualisations" - Concrete models or analogies used by teachers
• Particles can act as energy carriers • Transferring energy to a material makes the particles move more quickly • When heating a solid the particles vibrate more rapidly about a "fixed position". The amplitude of this vibration increases with increasing energy. • The increased amplitude of vibration results in the expansion of the solid • Energy from a heat source is transferred through solids by conduction, here particles pass on their energy to neighbours • Conduction will travel through a material in any direction • Good conductors such as metals have particles that can "vibrate" freely • In a liquid and in a gas particles move freely away from a heat source because they are not held so tightly together • Particles move freely in all directions resulting in a locally less dense medium that then rises upwards • This upwards movement is called convection. Convection currents can be seen in liquids and gases	• Conduction takes place in all directions • Heat travels incrementally along a bar (pins stuck on with wax gradually dropping off) • Some solids are better conductors than others because their particles can vibrate freely • Generally solids are better conductors than liquids because their particles are "held" closely together • Convection currents move in an upwards direction • When substances are heated they expand	• Spring connected polystyrene balls in the form of a cube can show the increased movement of particles carrying energy illustrating expansion and conduction • Be the model, link arms and pass on energy, for conduction • Pupils can hold hands and see that it is more difficult to transfer energy than when linking arms because they are further apart/held more loosely together (compare solid/liquid as good poor conductors) • Shove ha'penny can be used to illustrate transfer of energy in conduction and convection • 3D Kinetic model or CDRom can show expansion
Commentary: Pupils take readily to the notion of conduction as being energy transferred by increased vibrational energy that gradually passes through the solid. Drude's theory of heat conduction (1904) helps explain why metals conduct heat better than some other materials. This theory uses the idea of electrons being free to move transferring energy more quickly. This model, expected by some GCSE boards (not all), does have its problems. If the question arises as to why metals are better conductors it would be appropriate to say at this stage that the way the particles are held together in a metal means that they can more easily vibrate than the particles in other materials such as plastics, wood etc. Convection currents move upwards because the particles move away from each other near the heat source so the material, is less dense in this region. This "less dense" region then moves upwards		

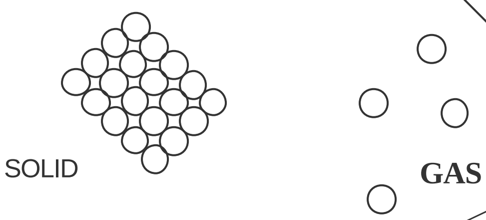
8I Heating and Cooling : Conduction

National Curriculum learning objectives

Explain conduction in terms of particle model

- Apply the particle model to explain why metals are good conductors and why fluids are poor conductors of heat

Consensus model



Concrete model

- Shove ha'penny
  coins touching
  coins not touching
- Pass the book

Students' ideas

What do YOU think?

Observations

- Observing conduction along metal rods – drawing pin stuck on with wax!
- Air trapped in a duvet keeps you warm

How does heat travel along a metal spoon?
Heating jiggles the nearest particle which passes on the movement

In a solid, what is heat?
The jiggling of particles

Why is air a poor conductor?
The particles are spaced out and unable to pass on the jiggle

Student Activities

- Observe the experiments – see pins drop off metal rod – compare the insulation of a fluffed up and flattened duvet
- Explain the process – the metal particles pass on the jiggle one to another
- Be the model – pass the book/link arms and pass the jiggle (transfer the energy)
- Devise your own model – it's like.....

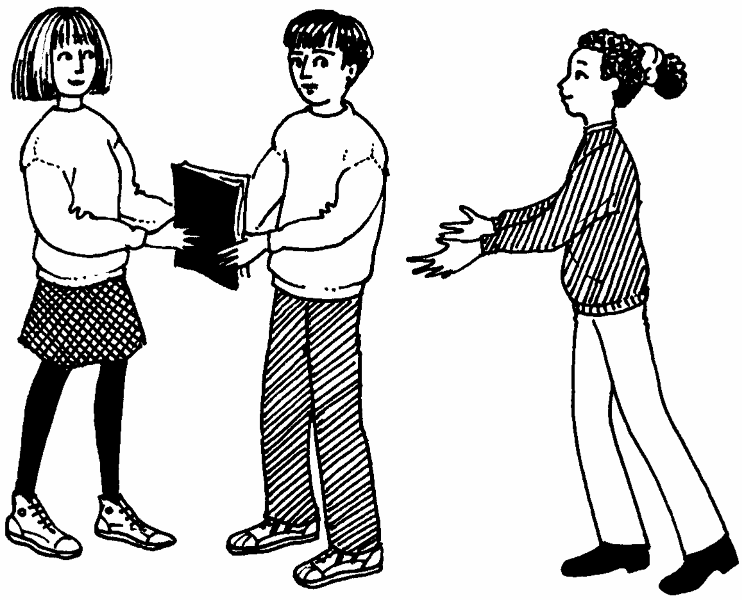
<u>Student Evaluation</u> e.g. Pass the book

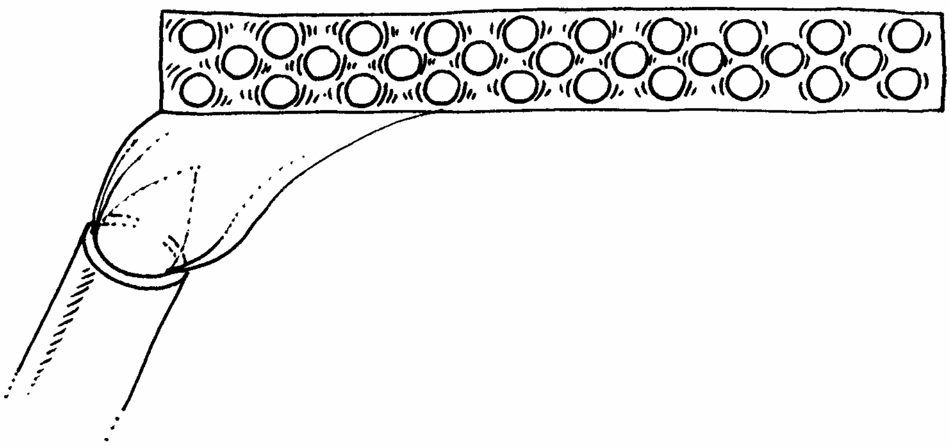
In what ways is the model good at helping you understand about particles?

Helps you imagine the way in which energy is passed from one particle to the next

In what ways is the model not good at helping you understand about particles?

Using the book as an energy packet does not help you imagine the jiggle!





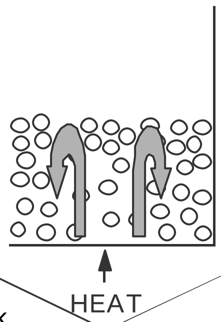
8I Heating and Cooling : Convection

National Curriculum learning objectives

Explain convection in terms of particle model

- Changes in movement due to energy transfers
- NB the **particles** don't expand, they spread out

Consensus model



Concrete model

- carry the book

Students' ideas

What do YOU think?

Observations

- Potassium permanganate in still water (heated, not stirred)
- Smoke moving in a smoke-box

Why does all of the water in a kettle get hot? *The heat energy causes particles to move faster and further.*

How does heat affect the particles? *It makes them travel.*

Why does the air above the ground shimmer on a hot day? *The particles spread out, air become less dense and rises.*

Student Activities

- Observe the experiments – track movement of heated air with smoke particles and coloured dye in heated water
- Explain the process – the heated air/water particles spread out, the air/water becomes less dense and rises..........etc
- Be the model – carry a book from A to B
- Devise your own model – it's like.....

<u>Student Evaluation</u> e.g. Carrying a book

In what ways is the model good at helping you understand about particles?

Helps you imagine that particles move and don't expand.

In what ways is the model not good at helping you understand about particles?

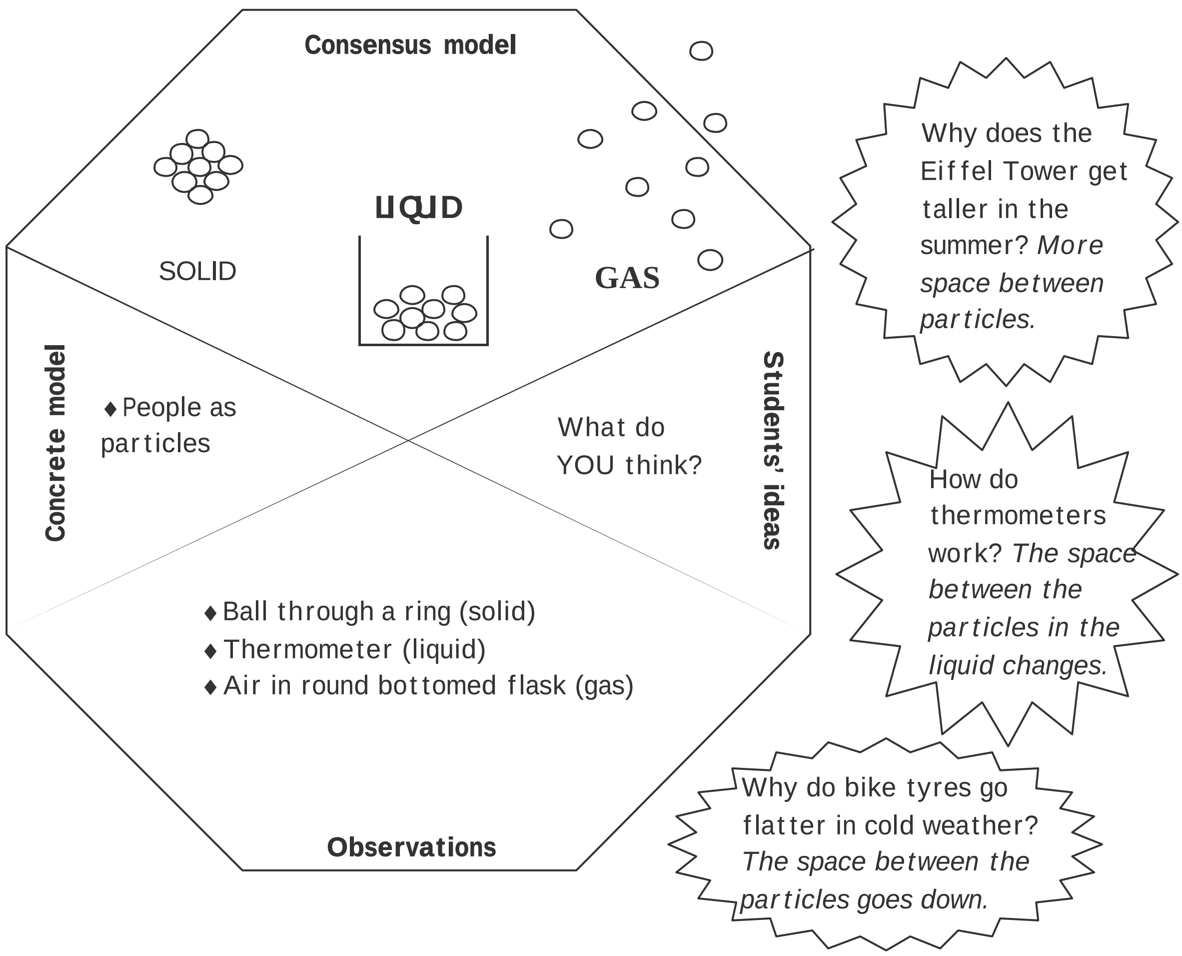
The book is an object unlike energy. Carrying the book does not show how the spacing of particles changes.

8I Heating and Cooling : Expansion

National Curriculum learning objectives

Explain expansion in terms of particle model

- Changes in movement, arrangement and bonding of particles due to energy transfers
- NB misconception – particles do not expand



Student Activities

- Observe the experiments – put the cold ball through the ring and then heat it up! Watch a thermometer change! Make bubbles in water by just holding a round bottomed flask
- Explain the process – if the substance is heated it expands, because the distance between the particles increases as they get more energy
- Be the model – act out being a solid, a liquid or a gas that is heated
- Devise your own model – it's like.....

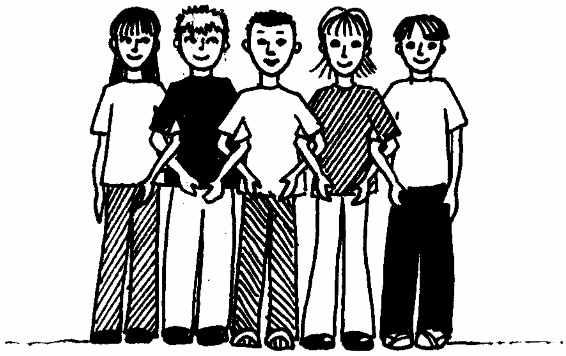
Student Evaluation   e.g. People as particles

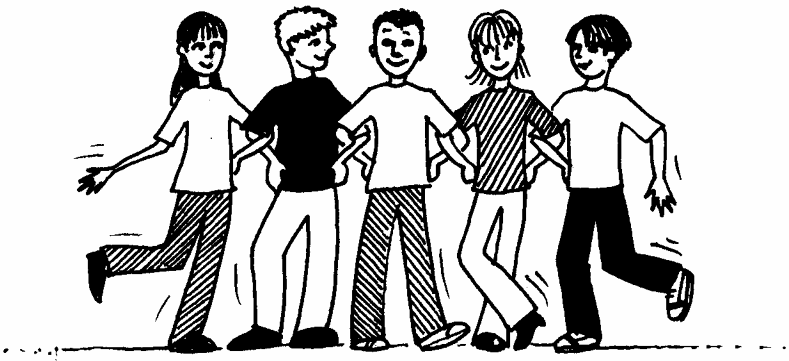
In what ways is the model good at helping you understand about particles?

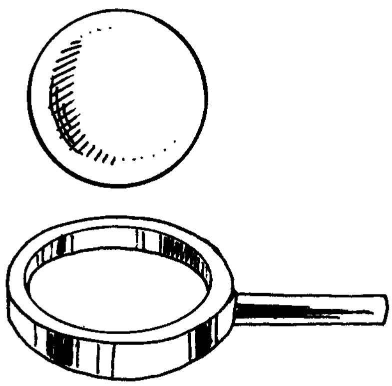
*It helps you see that it's the **space** that gets bigger or smaller*

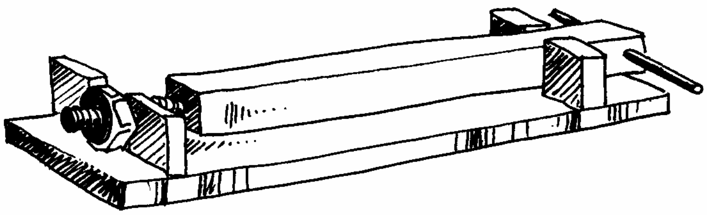
In what ways is the model not good at helping you understand about particles?

It's difficult to show the empty space between particles!







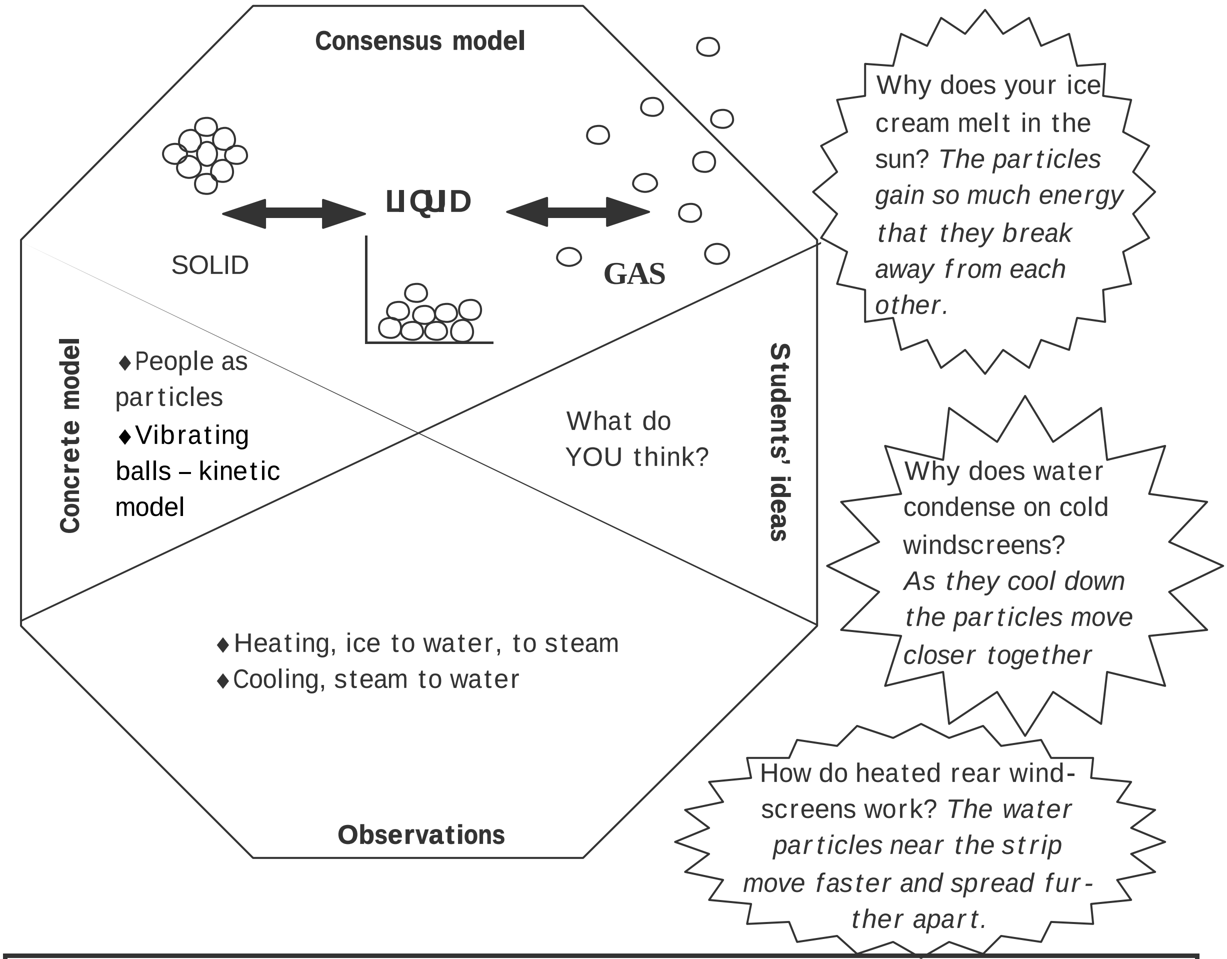


8I Heating and Cooling : Change of State

National Curriculum learning objectives

Explain change in state in terms of particle model

- ♦ Changes in movement, arrangement and bonding of particles due to energy transfers
- ♦ NB misconception – particles do not expand



Student Activities

- ♦ Observe the experiments – heating and cooling ice/water/steam – observe the spacing between vibrating balls in kinetic model
- ♦ Explain the process – if the solid/liquid is heated a lot, it melts/evaporates, because the particles have enough energy to move further away from each other
- ♦ Be the model – act out being the particles changing state
- ♦ Devise your own model -it's like.....

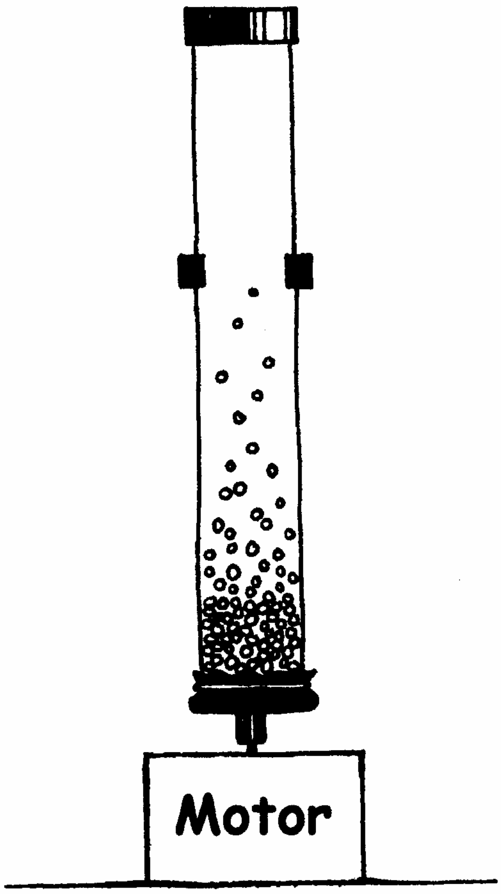
Student Evaluation e.g. People as particles

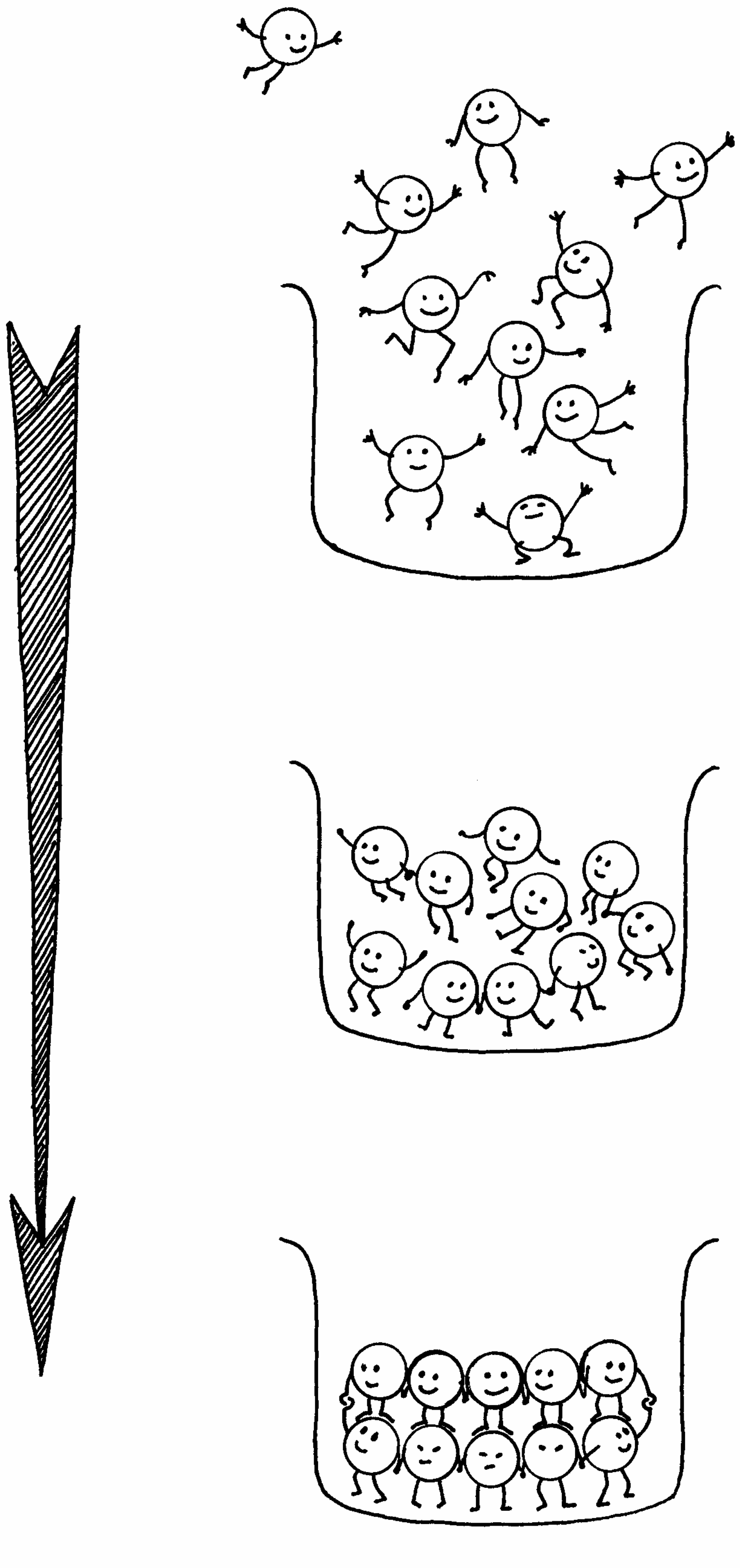
In what ways is the model good at helping you understand about particles?

It helps you see that the particles can gain enough energy to escape each other

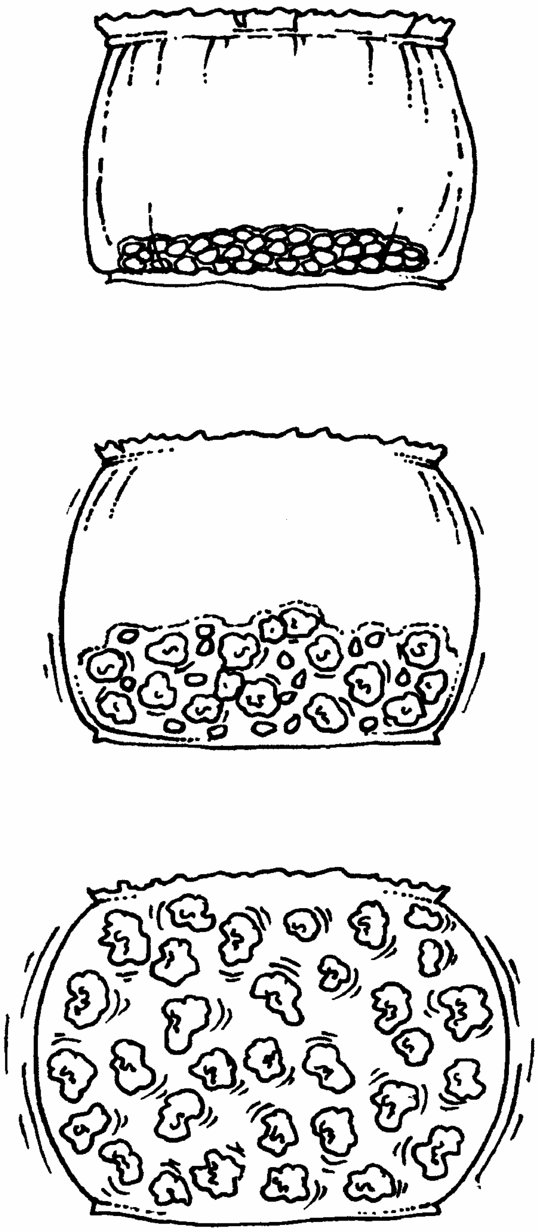
In what ways is the model not good at helping you understand about particles?

Particles move about randomly – people choose where they go!


Motor



What's good about the model?



What's bad about the model?

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Using models and analogies in the teaching of chemistry at KS3: Unit 8E Atoms and elements

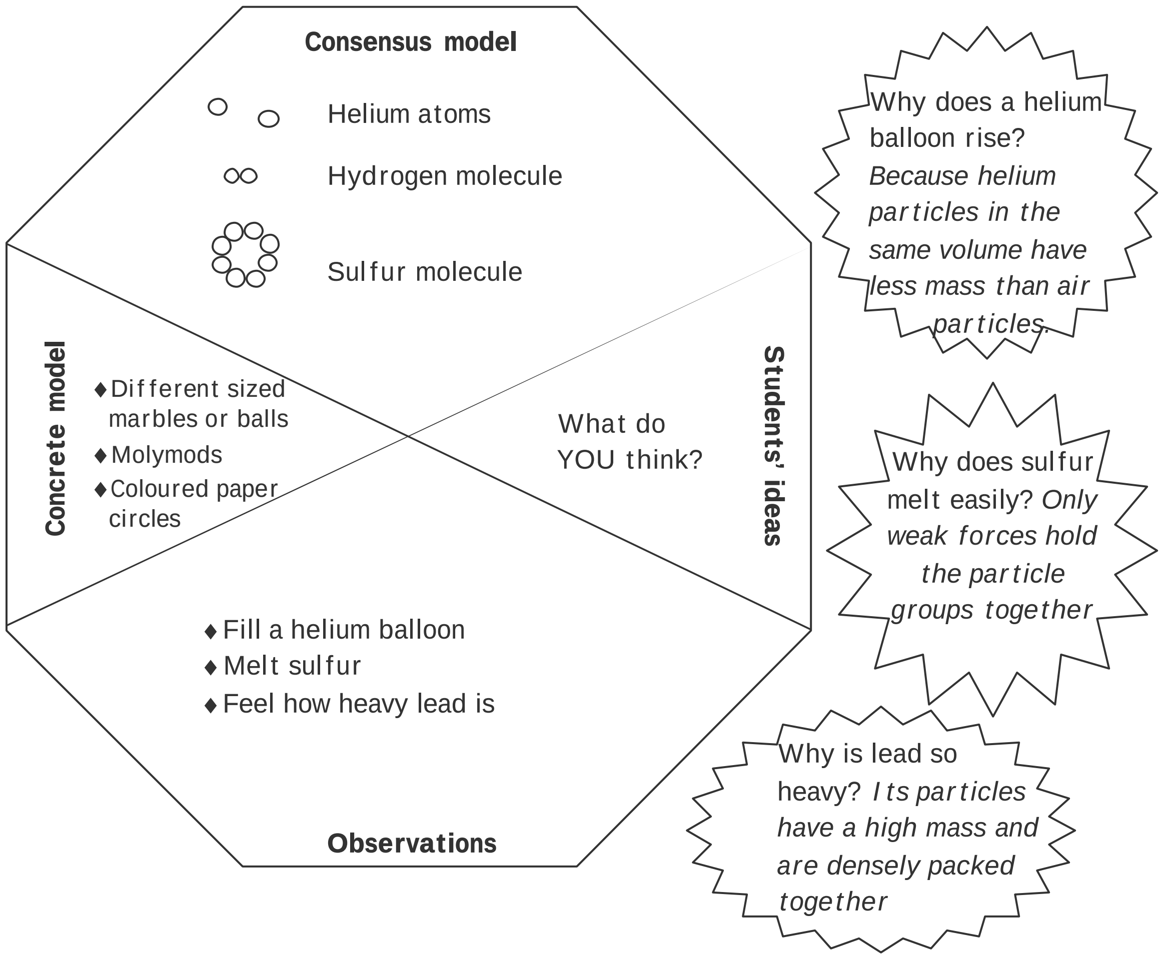
Key concepts	Phenomena that can be explained	"Visualisations" - Concrete models or analogies used by teachers
The atom is the basic building block of matter; and there are a relatively small number of different atoms Different substances arise as a result of different combinations of atoms; Elements consist of only one type of atom; Compounds consist of fixed combinations of different types of atoms; Atoms that are bonded together in a compound cannot easily be separated Atoms and combinations of atoms can be represented by symbols and formulae. Molecules are two or more atoms joined together Substances can be divided into elements, compounds and mixtures Chemical reactions can be represented in word equations and by models and diagrams There are 4 types of reactions:- Combination A+B→ AB Decomposition AB→ A+B Swapping partners AB +CD → AC +BD Displacement A +BC→AC +B	Compounds are formed from elements in predictable ways How chemical reactions take place and why mass is conserved Why energy transfers are always associated with chemical change and this is how we can recognise a chemical reaction	Use different sizes marbles or balls to show different atoms Use atomic models such as Molymod to model combinations of compounds, molecules Use Lego bricks to model combining atoms or types of reactions Use toffee/mint and mint toffee analogy to illustrate combination as in oxidation of metals or difference between compounds and mixtures Act out recombination of particles in reactions to "track" a reaction Make models of atoms using cards and track reactions

Commentary: We need to rehearse with pupils the terms atom and molecule, although it would also be appropriate to mention giant structures or ions. When dealing with chemical reactions it is important to stress that there are only a certain number of ways in which particles can rearrange themselves Pupils need to see reactions modelled with particles such as Molymod or Lego bricks as they carry them out, so they can see the particles being broken apart and reassembled. This needs to happen frequently rather than once or twice. In many ways it is easier for pupils to move from particles to drawings to symbols and equations and THEN to word equations rather than the other way. Stress the 4 types of reaction then match to type to reaction.

8E Atoms and Elements : Atoms

National Curriculum learning objectives

- Elements are made up of one sort of particle and these are called atoms
- Models can be used to illustrate phenomena that cannot be observed
- That atoms can combine to form molecules



Student Activities

- Observe the experiments – watch the balloon rise – watch melting sulfur in fume cupboard – feel lead and measure its density
- Explain the process – helium has particles with a small mass, sulfur melts as it has groups of particles with weak forces holding them together, iron has particles of a high mass, densely packed together.
- Be the model – act out particle groupings – people or objects of different mass
- Devise your own model - it's like.....

Student Evaluation e.g. Molymods

In what ways is the model good at helping you understand about particles?

It helps you see how elements are arranged in different ways

In what ways is the model not good at helping you understand about particles?

Atoms are so small you can't handle them individually

8E Atoms and elements : Compounds

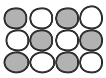
National Curriculum learning objectives

- That new materials are formed when atoms join together in different ways
- That compounds are formed when different kinds of atoms combine
- That atoms can combine to form molecules
- That atoms of elements combine to form molecules of compounds

Consensus model

 Hydrogen chloride gas

 Water

 Magnesium Oxide (giant structure not a little molecule)

Concrete model

- Lego bricks
- Molymods
- Card cut-outs 
- Toffees, mints and mint tof-

Students' ideas

What do YOU think?

Observations

- Concentrated HCl acid makes white HCl (aq) fumes when the HCl (g) meets water vapour in exhaled breath
- Burn magnesium metal in air
- Squeaky pop test for Hydrogen gas
- Red hot combustion spoon in chlorine gas makes iron III chloride

What liquid is made by the squeaky pop test?
Hydrogen joins with oxygen to make the compound, water

How can you make magnesium join with oxygen?
Heat magnesium in air

Why is it safe to take the lid off the gas jar at the end of the experiment?
The chlorine gas has combined with the iron

Student Activities

- Observe the experiments – a shiny metal forms a white solid – 2 colourless gases combine to form a colourless liquid – a green/yellow toxic gas combines with hot iron to form a brown solid
- Explain the process – particles are finding new 'partners' - (see 7F)
- Be the model – act out the recombination of the particles
- Devise your own model – it's like.....

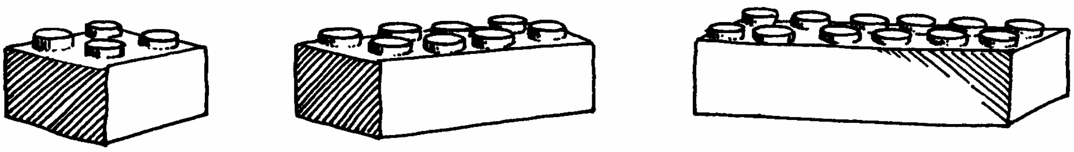
<u>Student Evaluation</u> e.g. Lego bricks

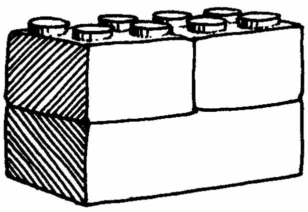
In what ways is the model good at helping you understand about particles?

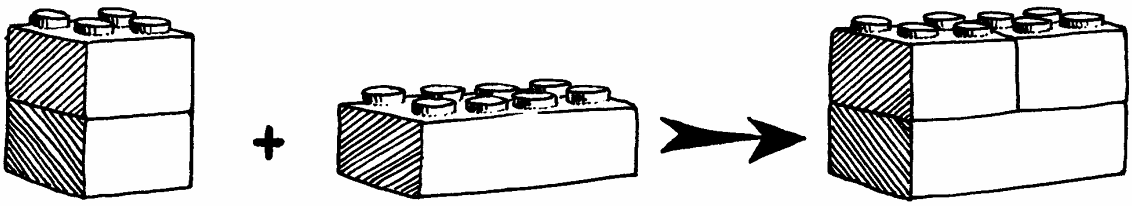
It shows the way that the molecule is made up

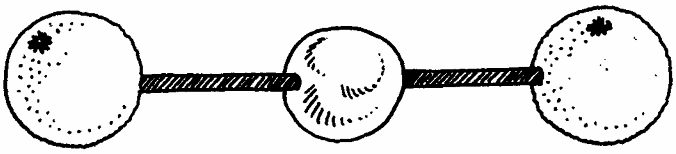
In what ways is the model not good at helping you understand about particles?

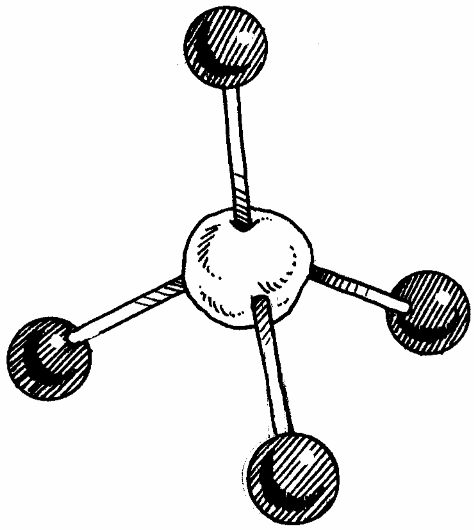
It doesn't show how the particles are held together or which elements will react

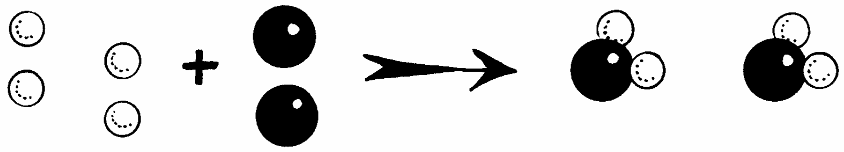


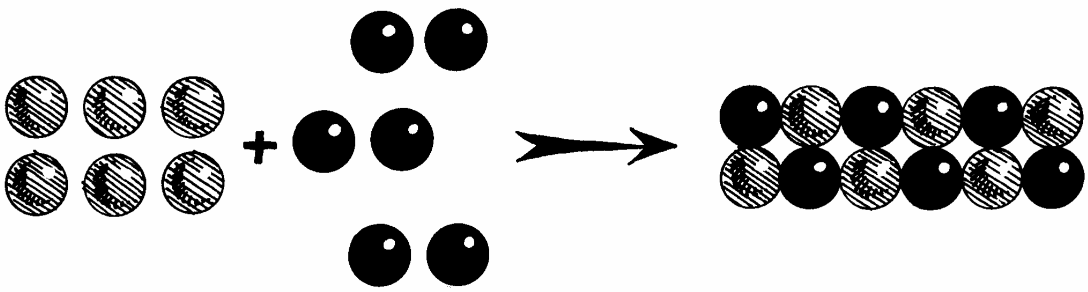








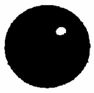




elements


oxygen


hydrogen

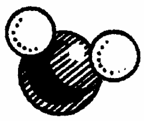

carbon

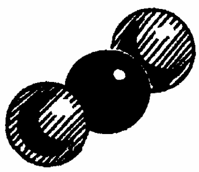
A

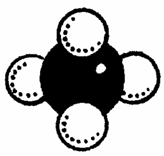
D

N

compounds


water


carbon dioxide


methane

AN

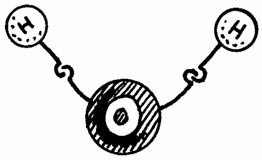
AND

DAN

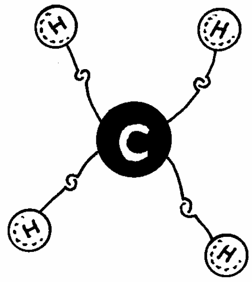
ADA

ADD

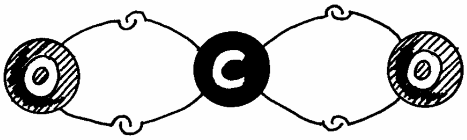
water



methane

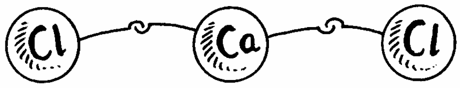


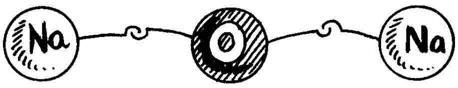
carbon dioxide



NaCl

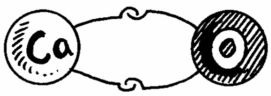
$CaCl_2$





Na_2O

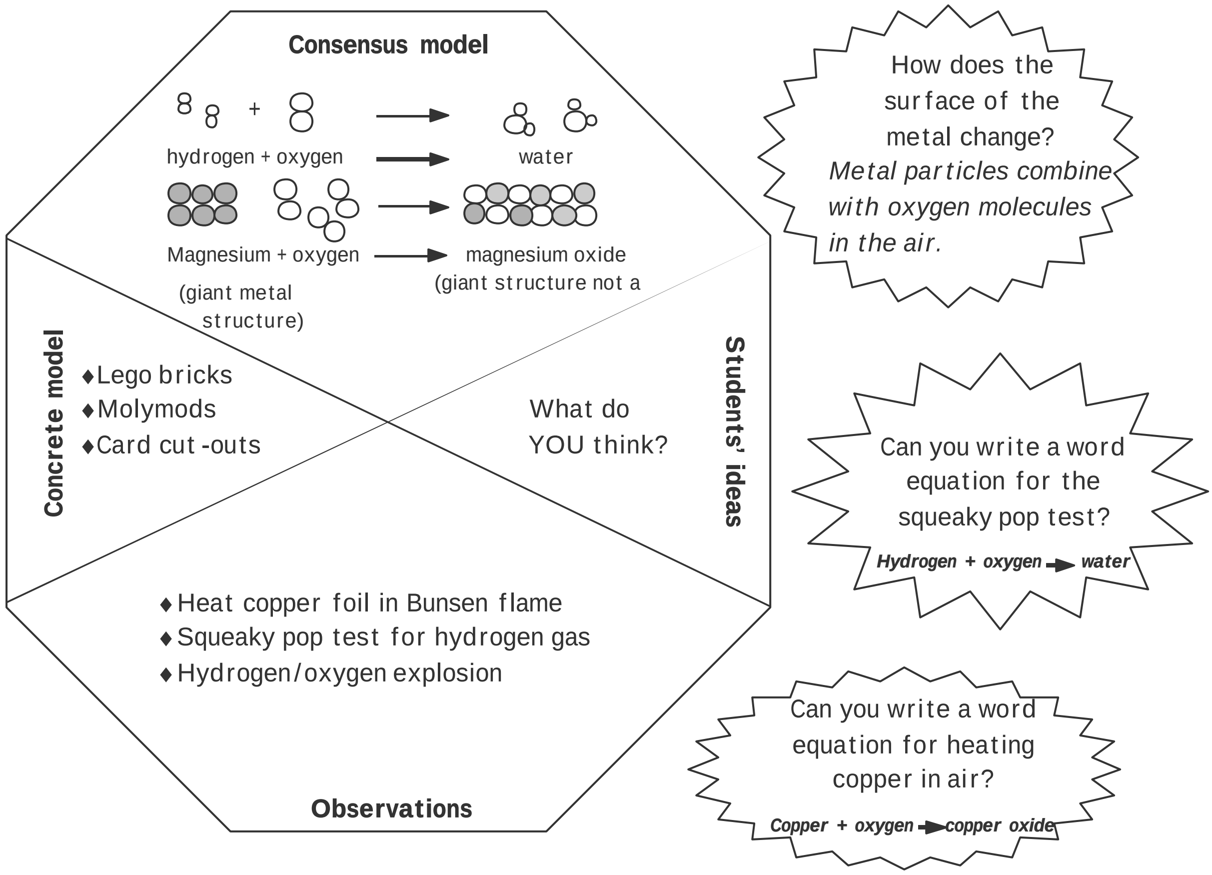
CaO



8E Atoms and elements : Representing word equations

National Curriculum learning objectives

- In chemical changes new substances are formed
- To represent and explain chemical reactions by word equations, models or diagrams



Student Activities

- Observe the experiments – copper metal becomes black – 2 colourless gases combine to form drops of a colourless liquid
- Explain the process – particles combine with different particles to make new substances
- Be the model – act out the recombination of the particles
- Devise your own model – it's like.....

<u>Student Evaluation</u> e.g. The consensus model

In what ways is the model good at helping you understand about particles?

It shows the 'correct' combination of particles to be able to write word equations

In what ways is the model not good at helping you understand about particles?

It doesn't show how the particles are linked together

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Using models and analogies in the teaching of chemistry at KS3: Unit 8F Compounds and mixtures

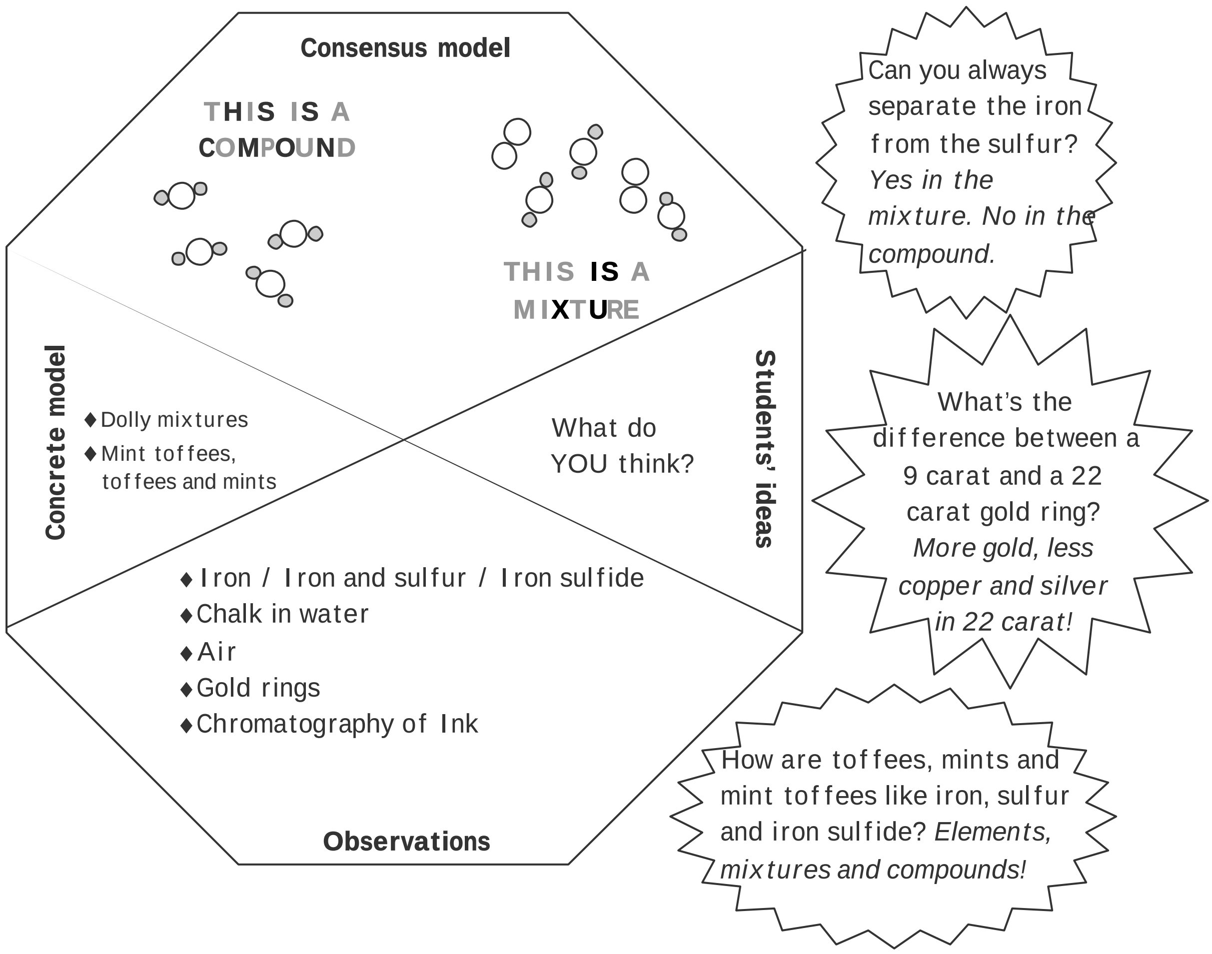
Key concepts	Phenomena that can be explained	"Visualisations" - Concrete models or analogies used by teachers
• Compounds are pure substances and mixtures are not • Compounds contain atoms of more than one kind joined together in fixed proportions. • Particles in a compound can be represented by formulae • Compounds are different from their elements because the atoms are chemically joined • Mixtures can exist in any proportion • Types of particles in a mixture can be separated relatively easily by physical means • Compounds can only be separated with relatively high energy inputs (e.g. by heating or electrolysis)	• Compounds melt at specific, fixed temperatures as do elements • Compounds are very different to the elements from which they are made • Mixtures (such as chocolate) do not melt at specific temperatures but over a temperature range • Chromatography (which relies on the extent to which substances dissolve) separates materials	• Lego Bricks or Molymod type atomic models can be used to create compounds and assist pupils in writing formulae • The use of Mints and Toffees and Mint toffees can be used to model the formation of compounds such as Iron Sulphide and Magnesuim Oxide • Raft analogy can be used to explain chromatography, rafts = mixtures, current = solvent, riverbed/stumps cause snags (selective absorption/stationary phase e.g. the filter paper) some rafts get snagged more easily than others
Commentary: Pupils do not always recognise compounds as pure substances because they contain different sorts of atoms. They need to see that every molecule in a compound is like any other. Physically modelling with sweets, breads, Lego bricks or chemical models can help enormously to give pupils "pictures in their heads". Modelling of physical and chemical processes using bricks, beads and models is vital to help pupils visualise and root the idea of the particulate nature of matter. It is a good idea to use a variety of types models (beads, Molymod, Lego and discuss what the models can explain and what they cannot. As with all cases it is important that pupils are made aware that we are modelling ideas and that different models have strengths and weaknesses.		

8F Compounds and Mixtures : Mixtures

National Curriculum learning objectives

Mixtures are 2 or more elements or compounds

- These can exist in any proportion



Student Activities

- Observe the experiments – look at iron and sulfur/separate the mixture/make the compound/try to separate the compound - see the chalk mix in water/separate it - separate inks – find out what 9 'carat' gold is!
- Explain the process – compounds are chemically joined/cannot easily be separated mixtures are not chemically joined/can be easily separated
- Be the model – act out the linking of particles in a compound
- Devise your own model – it's like.....

<u>Student Evaluation</u> e.g. Mints, toffees and mint toffees

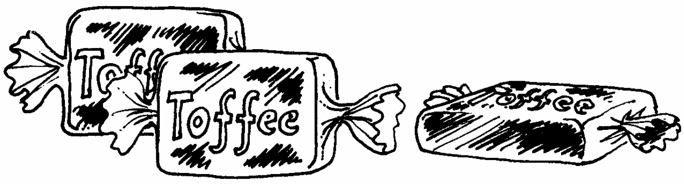
In what ways is the model good at helping you understand about particles?

It helps you imagine that the particles in compounds are chemically linked

In what ways is the model not good at helping you understand about particles?

It doesn' t help you understand which particles will chemically combine


MINT
MINT
MINT


Toffee
Toffee


Toffee
MINT
Toffee
MINT


MINT
TOFFEE
MINT
TOFFEE

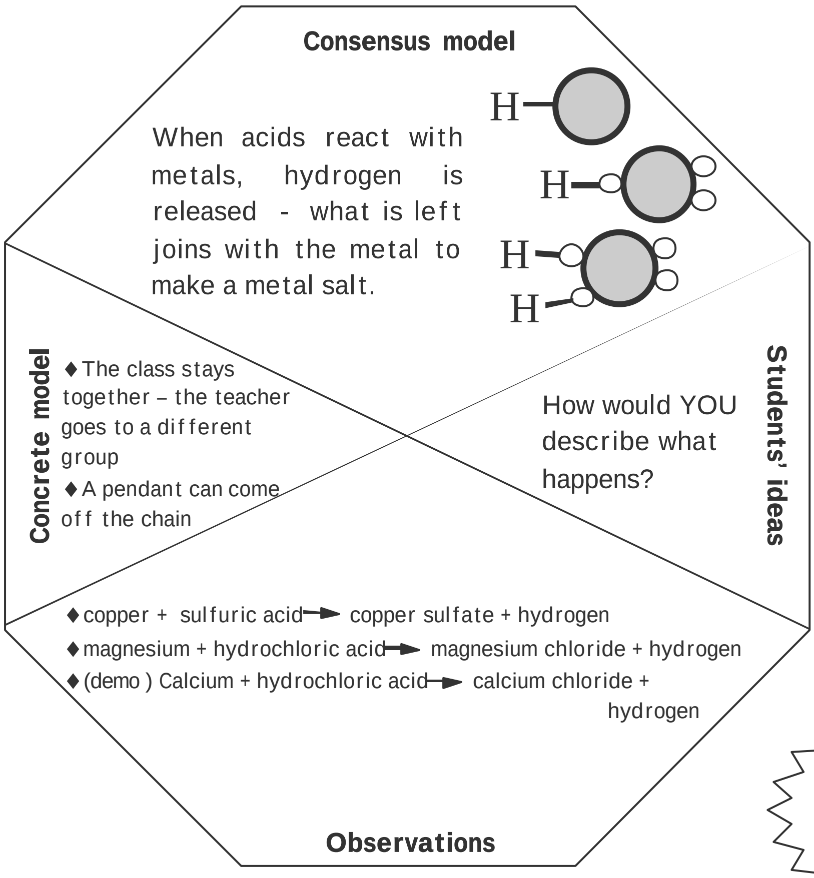
Using models and analogies in the teaching of chemistry at KS3: Unit 9E Metals and metal compounds

Key concepts	**Phenomena that can be explained**	**"Visualisations" - Concrete models or analogies used by teachers**
• Metals are good conductors of electricity and heat • Acids contain hydrogen • Metals and metal compounds react characteristically in the following ways ▪ Metal + acid → salt + hydrogen A+BC→AC + B (displacement) ▪ Metal carbonate + acid→ salt + water + carbon dioxide AB+CD→AC + BD (partner exchange) ▪ Acid + metal oxide → salt + water AB+CD→AC + BD (partner exchange) ▪ Acid + alkali→ salt + water AB+CD→AC + BD (partner exchange)	▪ the particle rearrangement models can be used to explain and predict the structure and names of products from given reactants	• Spring connected polystyrene balls in the form of a cube can show the increased movement of particles carrying energy illustrating expansion and conduction • Be the model, link arms and pass on energy, for conduction • Smarties can be used to represent energy being carried by current (cups) to represent conduction in metals • Lego bricks, Molymod cut out paper circles, cards or beads can be used to track different reactions
Commentary: Throughout the year 9 the exemplar units of the QCA scheme of work can be used to consolidate and confirm pupils ideas of the patterns of chemistry. Once again it is important for pupils to visualise the reactions that take place. Every opportunity should be taken to model the reaction using physical models and pupils should be encouraged to think about the limitations of the models as well as their strengths.		

9E Reactions of Metals and Metal Compounds : Metals and Acids

National Curriculum learning objectives

- To represent reactions of metals with dilute acids by word equations
- To use patterns in reactions to make predictions about other reactions



How do you know that hydrogen is made every time? *Squeaky pop test!*

Where does the hydrogen gas come from each time? *From the acid*

What happens to the metal particles? *They join with other particles to make a compound.*

Student Activities

- Observe the experiments – the metal 'disappears', gas bubbles form, metal salts go into solution
- Explain the process – particles combine with different particles to make new substances
- Be the model – act out the recombination of the particles
- Devise your own model – it's like.....

Student Evaluation

e.g. The consensus model

In what ways is the model good at helping you understand about particles?

It shows you how the acids have hydrogen in common

In what ways is the model not good at helping you understand about particles?

It doesn't show what forces keep the particles together

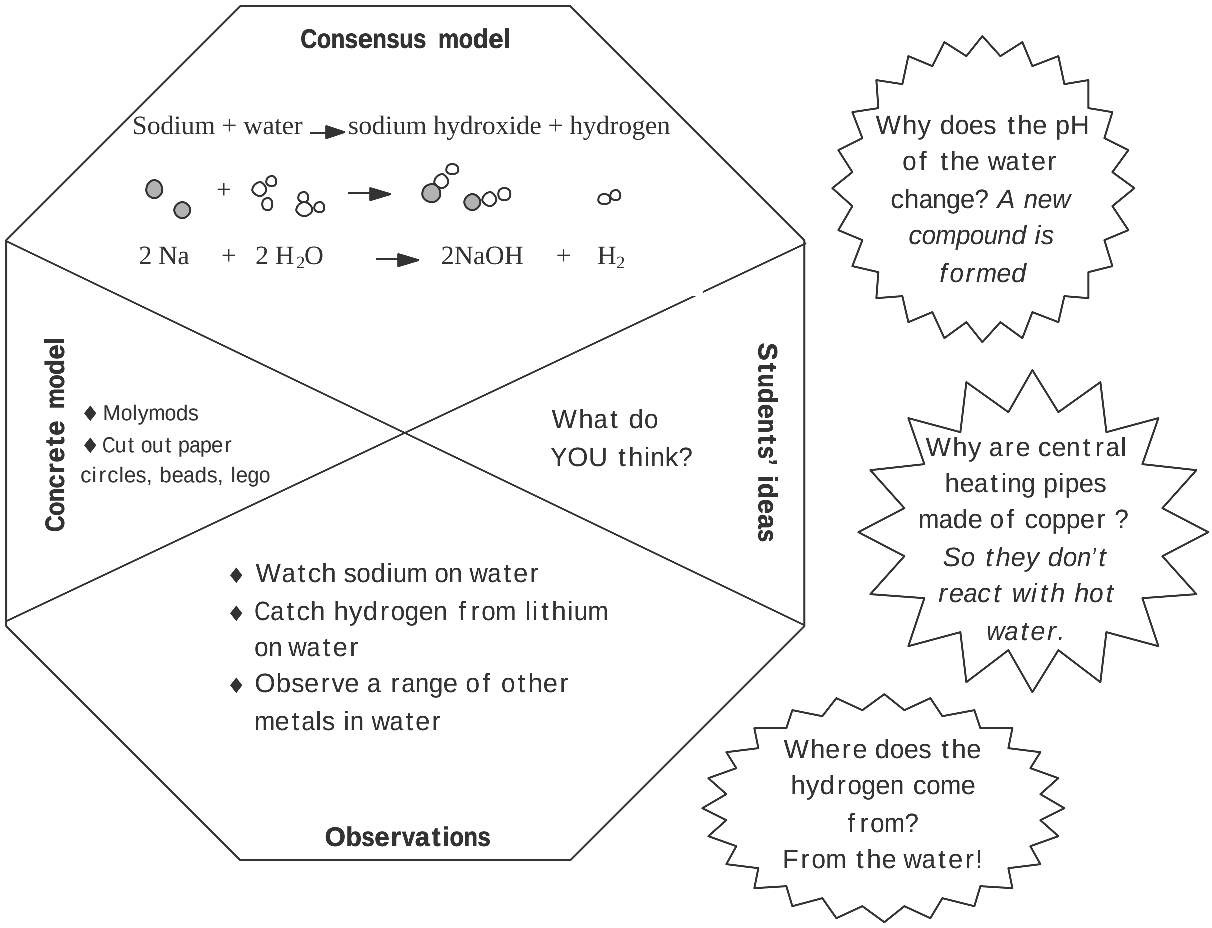
Using models and analogies in the teaching of chemistry at KS3: Unit 9F Patterns of Reactivity

<table>
<tr><th>Key concepts</th><th>Phenomena that can be explained</th><th>“Visualisations” - Concrete models or analogies used by teachers</th></tr>
<tr><td>Metals react characteristically in the following ways
Metal + oxygen → metal oxide
A+B→ AB (combination)
Metal + water→ metal hydroxide
A+B→ AB (combination)
Metals react with characteristic reactivity
More reactive metals will displace other metals from solutions of their salts</td><td>the particle rearrangement models can be used to explain and predict the structure of products from given reactants</td><td>Lego bricks, Molymod cut out paper circles, cards or beads can be used to track different reactions
Atomic models can be developed to explain reactivity</td></tr>
<tr><td colspan="3">Commentary: The reactivity series of metals is the one key pattern that is established in this unit. Pupils are encouraged to use this to identify patterns of reactions and see how displacement reactions can be useful. Consideration of the models used so far to represent and track chemical reactions should lead pupils to recognise that the model used so far is not good enough to explain the different reactivity of metals. Therefore to attempt explanation requires a more sophisticated model i.e. a recognition of the part electrons play in chemistry and atomic structure. Whilst atomic structure is reserved for key stage 4 there is no reason why for those pupils for whom it is appropriate a simple explanation using atomic structure cannot be used. Pupils can be encouraged to make their own models to represent some metals such as lithium, magnesium. Even if pupils do not go on to consider atomic models it is important to recognise that our particulate model is not “good enough” to explain why reactions occur.</td></tr>
</table>

9F Patterns of Reactivity : Metals and Water

National Curriculum learning objectives

- That many metals are affected by water
- That metals are affected in different ways
- That some metals react with cold water to produce hydrogen
- That some metals react more readily with water than others



Student Activities

- Observe the experiments – demonstrate more reactive metals on water – carry out squeaky pop test on the hydrogen from lithium – observe the reactions of a range of metals on water
- Explain the process – the more reactive metals take the place of some of the hydrogen in water
- Be the model – act out displacement of hydrogen from water, by a reactive metal
- Devise your own model – it's like.....

Student Evaluation

e.g. Paper circles

In what ways is the model good at helping you understand about particles?

It shows where the hydrogen comes from.

In what ways is the model not good at helping you understand about particles?

The particles of sodium are not widely separated in the solid metal

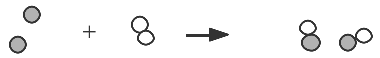
9F Patterns of Reactivity : Metals and Air

National Curriculum learning objectives

- That many metals are affected by (the oxygen in) the air
- That metals are affected in different ways
- That some metals are soft and can be cut

Consensus model

Magnesium + oxygen → Magnesium Oxide



$2\,Mg + O_2 \rightarrow 2MgO$

Concrete model

- Molymods
- Cut out paper circles, beads, lego

Students' ideas

What do YOU think?

Observations

- Watch freshly cut sodium go dull
- Heat iron filings in air to form rust
- Heat shiny copper foil in air to form a black solid

How long does it take for a nail to go rusty? *A few days – because iron isn't very reactive.*

Why do lots of churches have lead roofs ? *Because lead doesn't react with cold air.*

Which metals do people chose for jewellery? *The ones that don't react with air.*

Student Activities

- Observe the experiments – demonstrate more reactive metals react spontaneously with air – observe that less reactive metals must be heated before they will react
- Explain the process – the more reactive metals can form new compounds with oxygen
- Be the model – act out breaking of the bonds in oxygen and the formation of a new compound
- Devise your own model – it's like.....

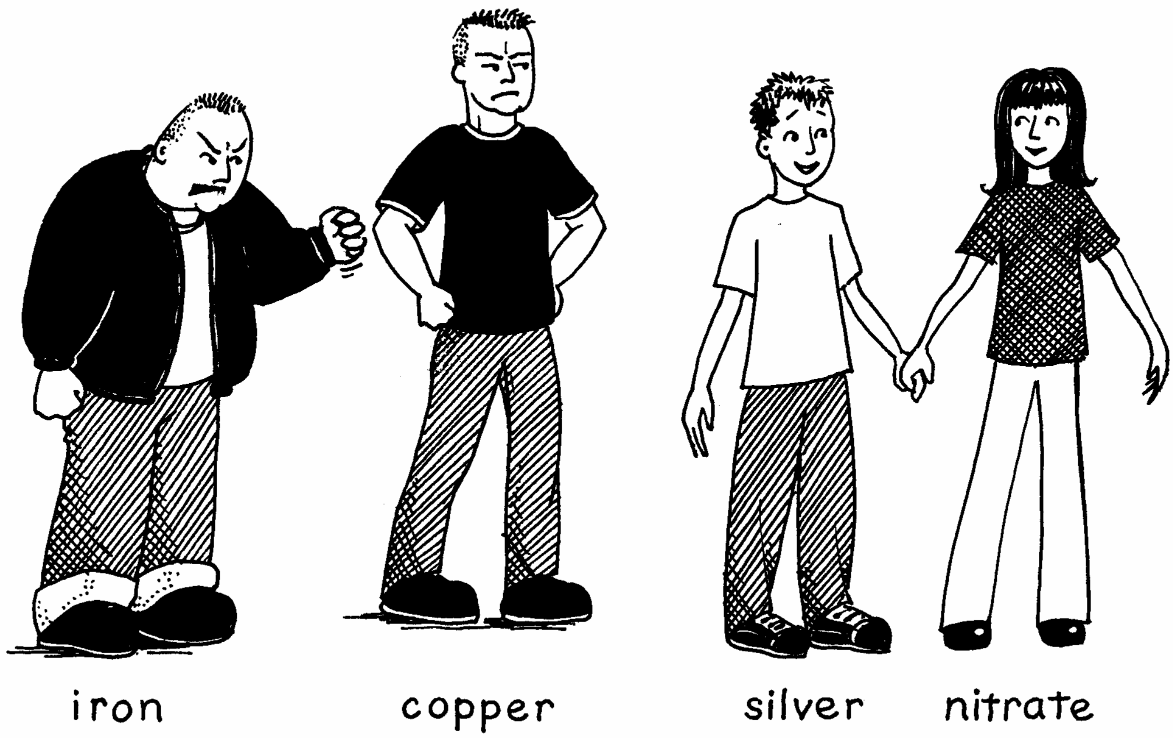
Student Evaluation   e.g. Molymods

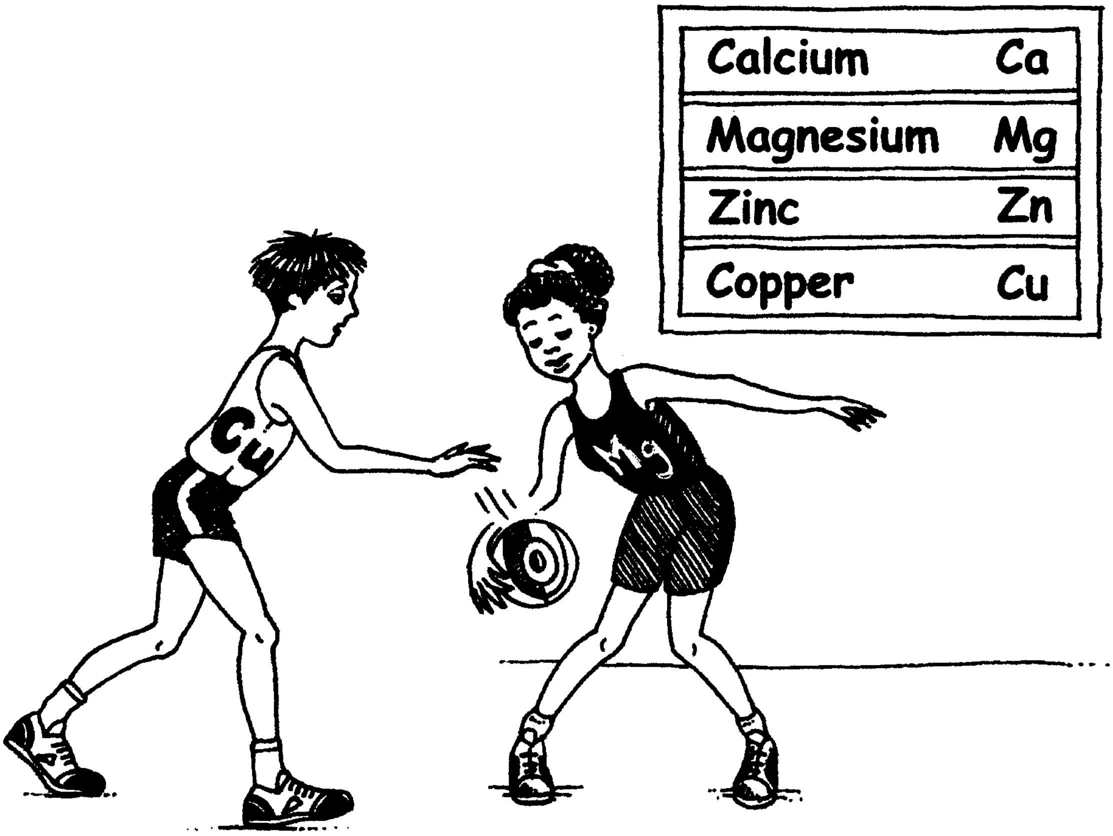
In what ways is the model good at helping you understand about particles?

It helps you to see how new compounds form

In what ways is the model not good at helping you understand about particles?

Particles of magnesium and magnesium oxide are not widely separated in the solid metal and magnesium oxide


iron
copper
silver
nitrate


Calcium Ca
Magnesium Mg
Zinc Zn
Copper Cu
Cu
Mg

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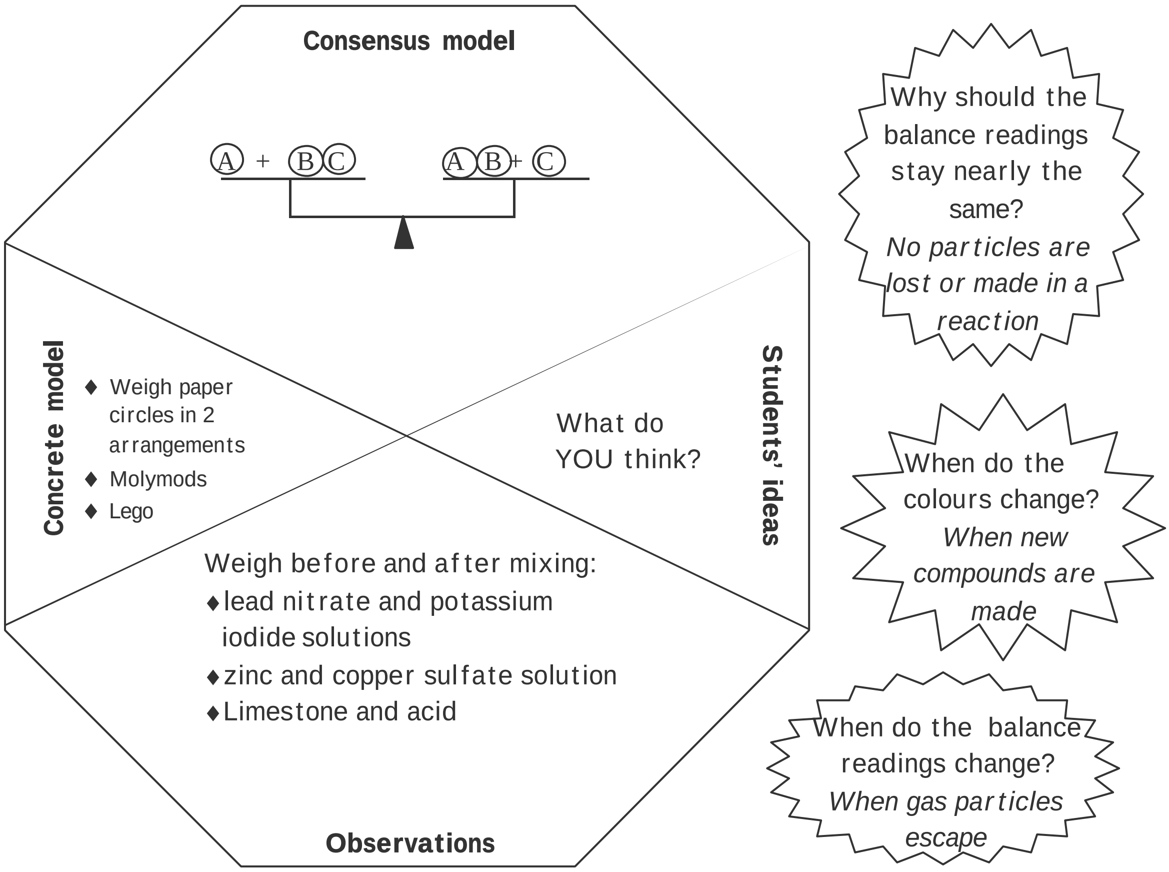
Using models and analogies in the teaching of chemistry at KS3: Unit 9H Using Chemistry

Key concepts	Phenomena that can be explained	"Visualisations" - Concrete models or analogies used by teachers
• Chemical reactions can be represented in word equations and by models and diagrams using formulae and equations • There are 4 types of reactions:- • Combination A+B→ AB • Decomposition AB→ A+B • Partner exchange AB +CD → AC +BD • Displacement A +BC→AC +B	▪ the particle rearrangement models can be used to explain and predict the structure of products from given reactants	• Lego bricks, Molymod cut out paper circles, cards or beads can be used to track different reactions
Commentary: This unit brings together and consolidates many of the ideas about chemistry throughout KS3 including the burning of fuels, using chemical reactions as energy sources and recognising that chemical reactions involve a transfer of energy. A principal message re-established is that mass is conserved in chemical reactions. If pupils have had many experiences to model chemical reactions as they take place this should not be an issue and should be obvious to most. Care needs to be taken to check that pupils do see air as containing particles and that these particles have mass		

9H Using Chemistry : Conservation of Mass

National Curriculum learning objectives

- Use models to describe conservation of mass in a reaction
- Use models or simulations to show how particles combine in different ways as a result of a reaction



Student Activities

- Observe the experiments – see that the balance readings are the same before and after mixing, except when a gas escapes
- Explain the process – particles don't disappear but sometimes it's hard to weigh them all!
- Be the model – act out rearrangement of particles – don't let any escape!
- Devise your own model – it's like.....

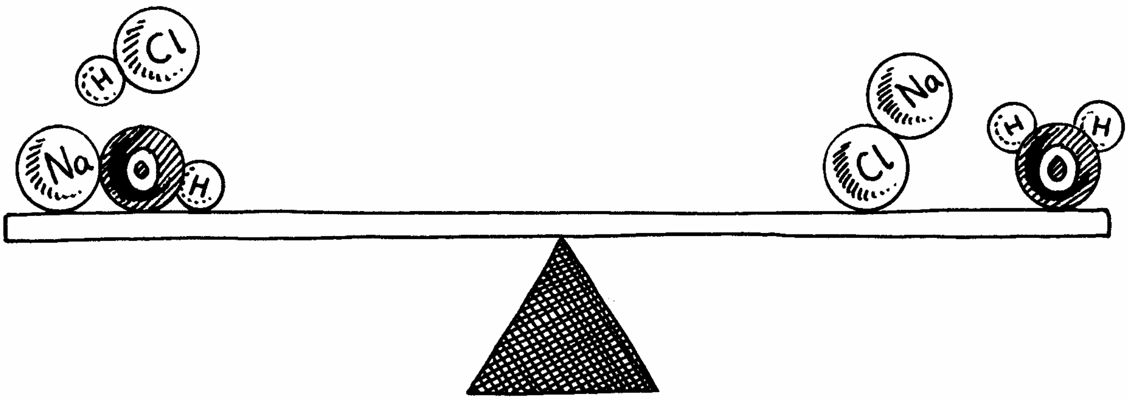
Student Evaluation   e.g. Weighing paper circles

In what ways is the model good at helping you understand about particles?

It helps you explain how mass is always conserved, even when the balance changes

In what ways is the model not good at helping you understand about particles?

The real particles are too small to weigh one by one



H
Cl
Na
O
H
Na
Cl
H
O
H

9H Using Chemistry : Word equations

National Curriculum learning objectives

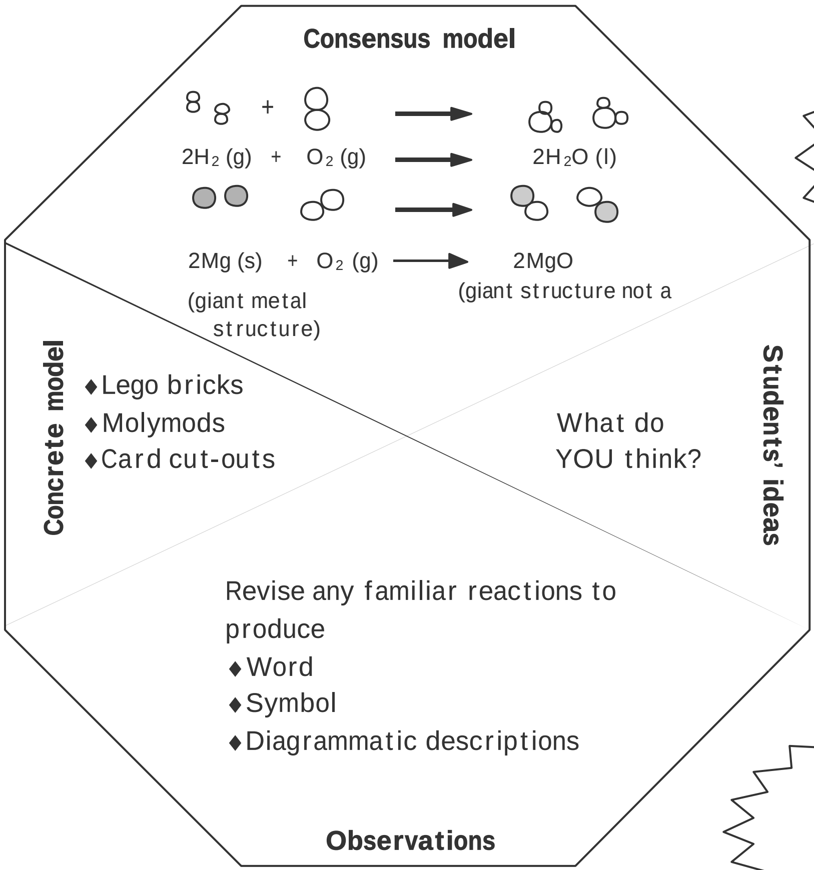
- Represent the reactions by word or symbol equations or diagrammatically

♦ Metal + Acid = Metal Salt + Hydrogen

♦ Metal Oxide + Acid = Metal Salt + Water

♦ Metal Carbonate + Acid = Metal Salt + Carbon Dioxide + Water

♦ Element + Oxygen = Oxide Compound



What do you notice about the oxygen particles?
There are the same numbers on both sides of the equation.

Can you see a reaction that would lose mass?
No, there are the same numbers of particles on both sides.

What do the letters in the brackets mean?
The particles are in a solid, liquid or gas state

Student Activities

- Observe the experiments – use familiar reactions to interpret as word and symbol equations
- Explain the process – reinforce the idea that particles recombine in a chemical reaction – none are 'lost'
- Be the model – act out the recombination of the particles
- Devise your own model – it's like.....

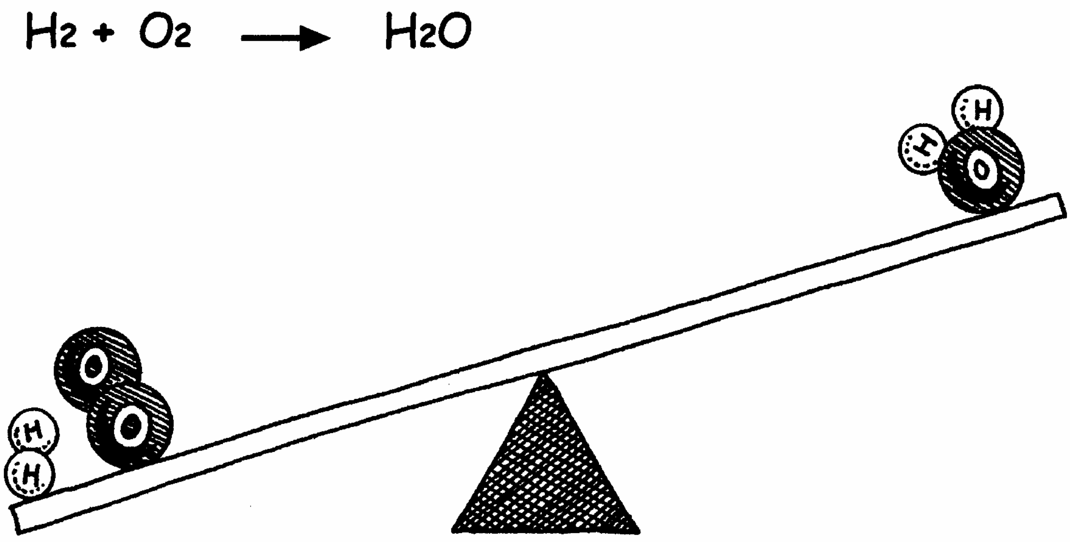
Student Evaluation e.g. card cut outs

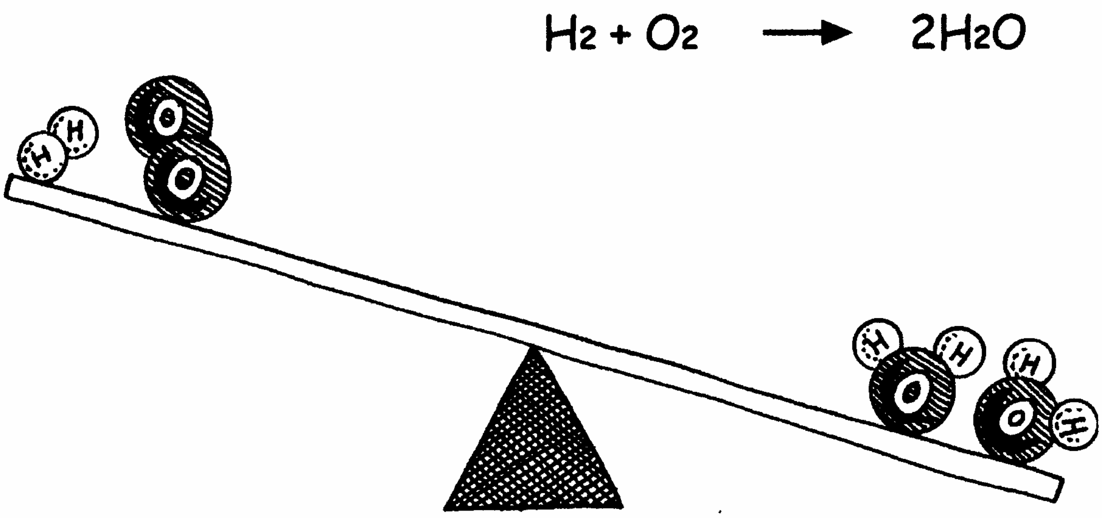
In what ways is the model good at helping you understand about particles?

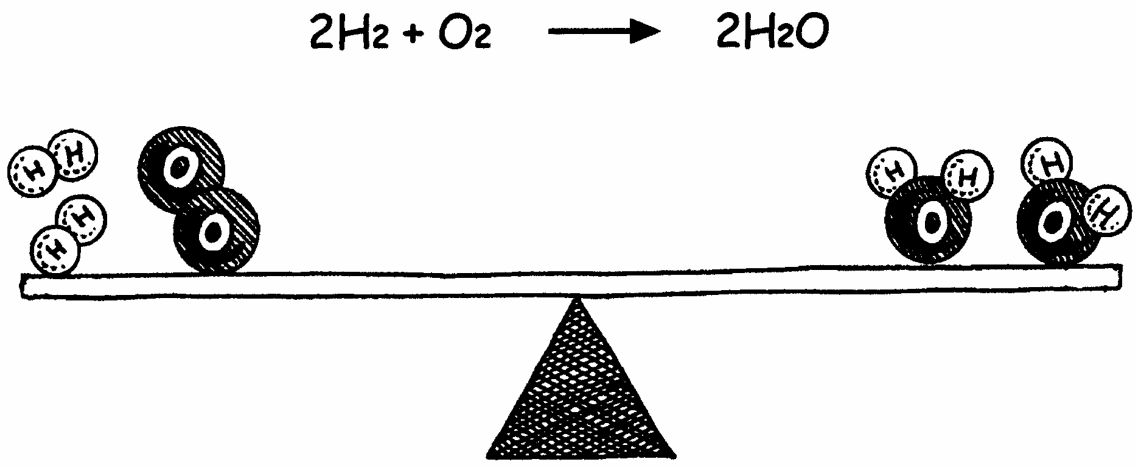
It shows the 'correct' combination of particles to write word equations

In what ways is the model not good at helping you understand about particles?

It doesn't show how the particles are linked together


H2 + O2 → H2O
H
H
O
O
H
H
O

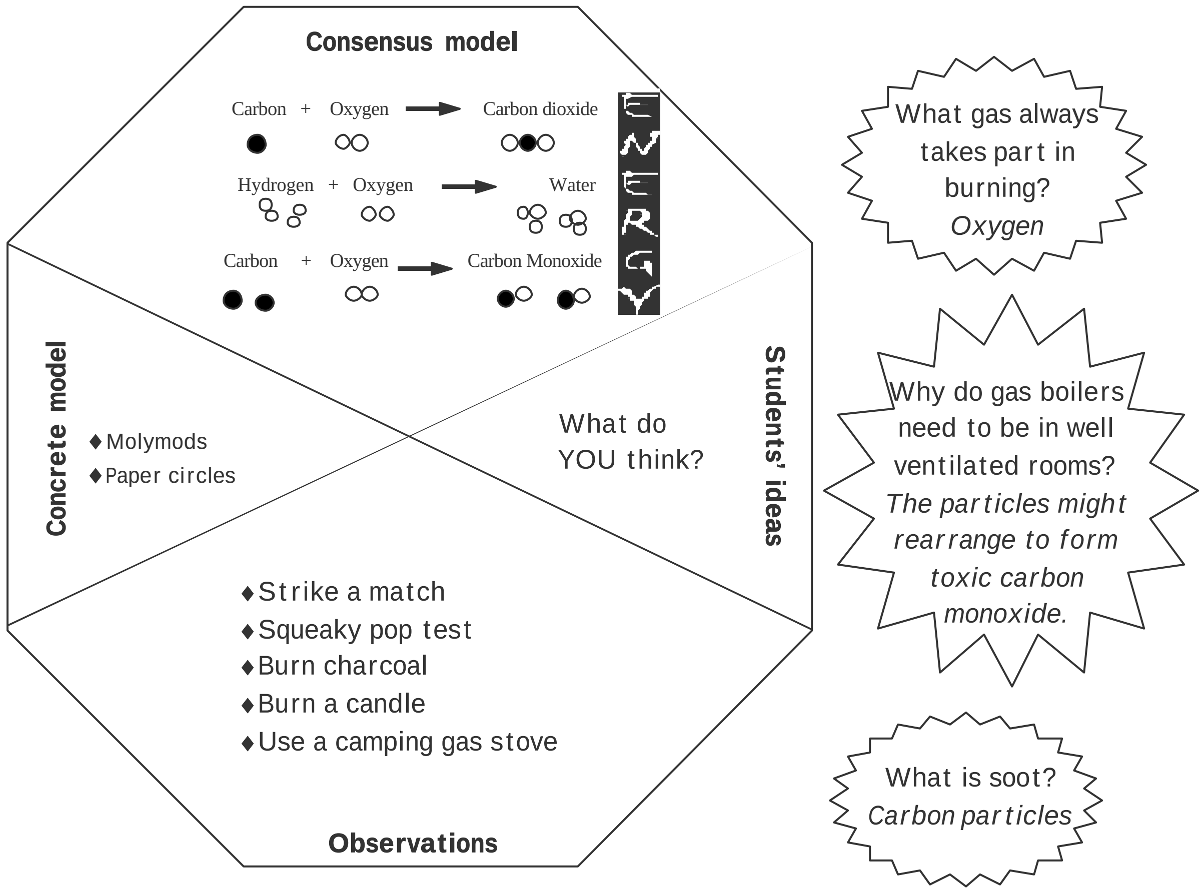

H2 + O2 → 2H2O


2H2 + O2 → 2H2O
H
H
H
H
O
O
H
H
O
H
H
O

9H Using Chemistry : Burning Fuels

National Curriculum learning objectives

- ♦ That fuels burn and release energy
- ♦ That when fuels containing hydrogen and carbon burn, water, carbon dioxide and sometimes carbon monoxide and soot are formed



Student Activities

- ♦ Observe the experiments – Sir Humphrey Davey saw 42 different things when he burnt a candle. Can you?
- ♦ Explain the process – when a match burns the elements carbon, and hydrogen in the wood recombine with oxygen to form mainly carbon dioxide and water. Some of the carbon remains uncombined as charcoal.
- ♦ Be the model – make a student 'match' with elements Carbon and Hydrogen –act out burning with the addition of oxygen

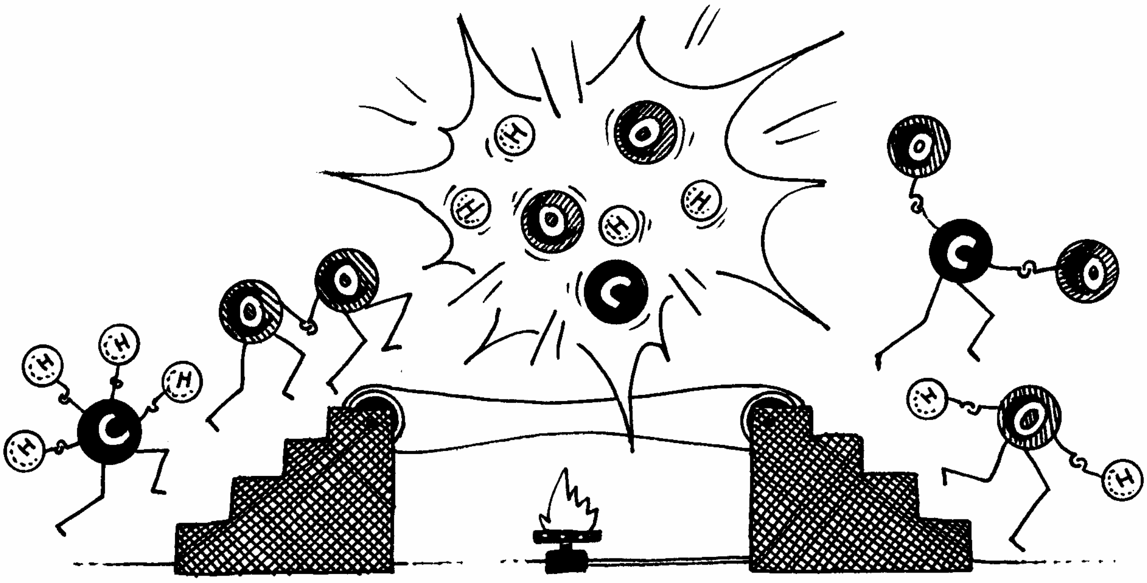
Student Evaluation e.g. Paper circles

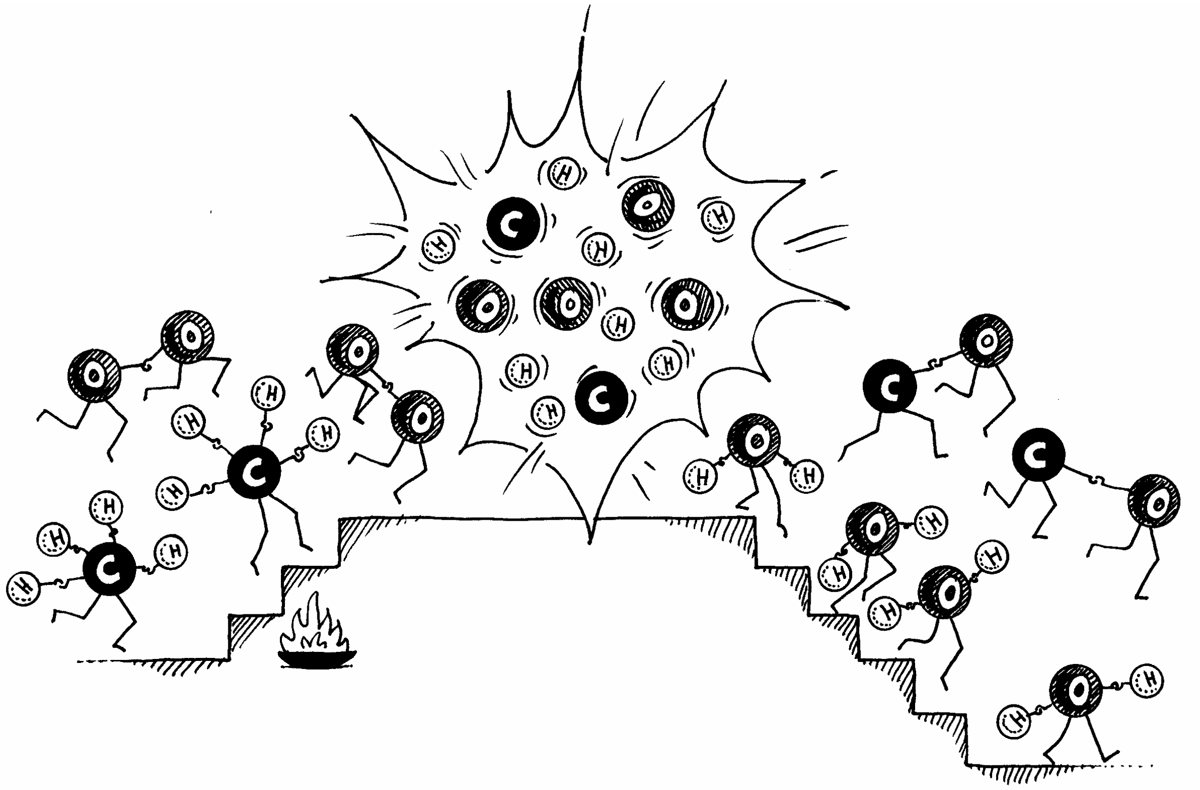
In what ways is the model good at helping you understand about particles?

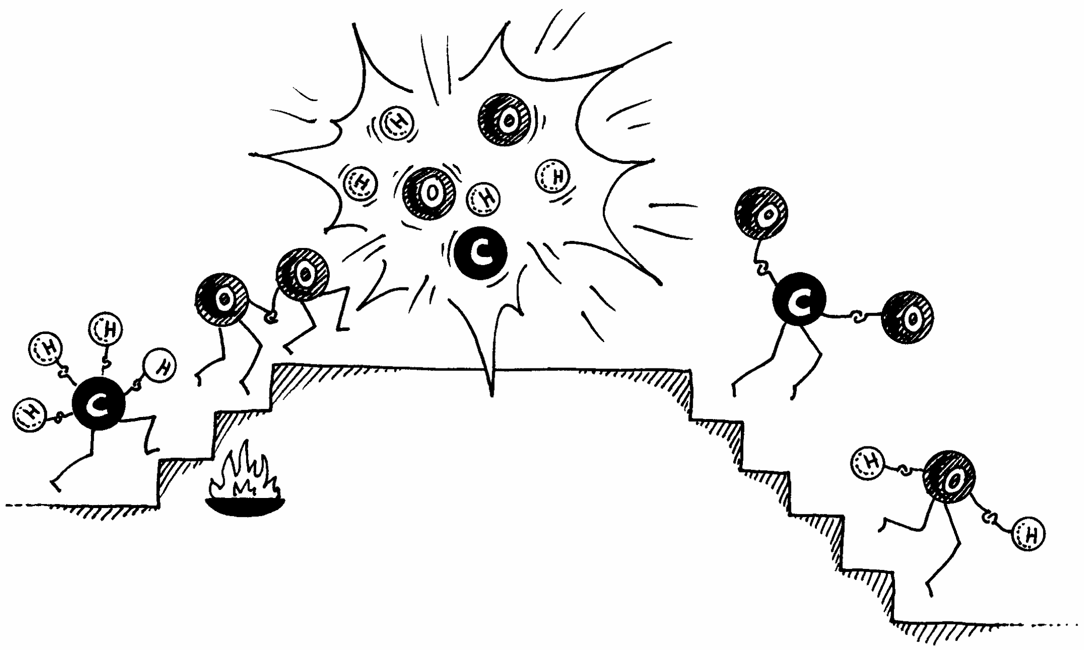
It helps you see that nothing vanishes, even the new gases which form are seen.

In what ways is the model not good at helping you understand about particles?

Carbon doesn't exist as individual atoms but as large molecules







Models in teaching Chemistry – the research evidence

This is NOT a comprehensive review of research related to models in science teaching, but highlights some important research findings which have implications for practice.

What are models ?

A model is a representation of an object, event or idea. This representation creates a vehicle through which the object, event or idea can be conceptualised and understood.

Models are important in science teaching, as major tools for teaching and learning. They are more than this, however. Models are one of the main products of science – the progress of science is normally marked by the production of a series of models, each associated with a distinctive theory. Modelling is a major element in scientific methodology (Gilbert, 1994).

Models can be of a number of different types (Gilbert, 1998):
Mental model – that we each of us visualise in our mind;
Expressed model – when we try to explain or present in another form our mental model;
Consensus model – an expressed model which has gained acceptance within the scientific community;
Historical model – a *consensus* model which has been superseded at the 'cutting edge' of science e.g. the 'plum pudding' model of an atom is an historical model superseded by 'orbiting electrons' model.
A *teaching* model is one specifically produced to teach a difficult *consensus* or *historical* model.

The last four models can be put forward in a number of different ways including as objects, symbolic or mathematical representations, diagrams, spoken explanations or a mixture of these.

Mayer (1989) defined a good model as one that fulfils the following criteria (the 6 Cs):

I. structurally *complete* in the relationship of its elements - ie has all the essential elements of the target idea;
II. *coherent* and appropriate in its level of detail;
III. *considerate* in its form – appropriate vocabulary and form of presentation;
IV. *concrete* in its representation – the relationship of all parts of the model are obvious;
V. provides clear *conceptual* explanation – the associated theory can be explained through the model;
VI. highlights the *correct* comparatives between the model and the target idea – the scope and limitations of the model are pointed out.

These '6Cs' can be used to evaluate the effectiveness of a model in exploring the target idea.

How can models be used effectively in chemistry teaching?

Some studies have sought to describe the actions of teachers in using models, others have attempted to evaluate the use of models in helping pupils' understanding.

Jarman (1996) explored the extent to which beginning teachers used analogies in their 'normal' science teaching. She asked a cohort of PGCE students to keep a record of the types of analogies they used in explaining ideas. She found that 58% of the models were devised by the student teachers, mostly spontaneously but sometimes planned. Some models were culled from experienced teachers (20%) or textbooks (15%) with just a few (4%) from the student teachers previous experience of science education. The most frequent use of models in chemistry teaching for these student teachers was in explaining particulate nature of matter and rates of reaction. People, animals and familiar activities, such as making cakes, were frequent sources for models.

The student teachers presented the following reasons for using analogies:

I. To help pupils visualise a structure or process;
II. To help less able pupils to remember a concept or idea;
III. To simplify a difficult concept or idea;
IV. Because the pupils failed to understand a concept or idea on an earlier occasion;
V. To help the pupils link an unfamiliar idea with a familiar idea, particularly in an imaginative way;
VI. To entertain or to provide a variety of approach;
VII. Because the pupils were encountering a concept or idea for the first time.

A similar study was conducted by Thiele and Treagust (1994) in which they examined the models used by four experienced chemistry teachers. Figure 1 shows the analogies used. They showed that these four teachers had some similar characteristics to the PGCE students in Jarman's study in using models:

A. Teachers used analogies when they considered that the students had not understood an initial explanation;
B. There was little evidence that teachers preplanned their analogies;
C. Teachers tended to draw on their own experience or own professional reading as a source of analogies;
D. Pictorial analogies were frequently used in lessons;
E. Two of the teachers provided clear statements of the limitations of the analogies.

Figure 1 Analogies used by four chemistry teachers across 43 lessons

ANALOG	TARGET
Energy effects	
Pole vaulter attempting a vault	Activation energy
Car precariously located at the top of a hill	High energy of the activated complex
Reaction rates	
Students hurdling hurdles of different heights	Rates of various reactions having different activation energies
The student dance	Increasing in molecular velocities causing an increasing number of collisions
Coconut shy	Effect of increasing concentration on the number of successful collisions
Climbing through a Swiss mountain pass	Effect of catalysts on reaction mechanism and rate
Pushing a car around a side road	Ease of catalysed reaction mechanism
Chipmunks storing food before winter	Exothermic and endothermic reactions
Chemical Equilibrium	
Breaking apart a pen and its cap	Energy required to break chemical bonds
Water flowing in and out of a sink	Constant dynamic properties in a steady state open system
Gravitational effects on a body Elastic band returning to its original size	Tendency of a chemical system to revert ot equilibrium
People moving in and out of a shop	Rates of forward and reverse reactions for equilibrium
Person walking up a down escalator	Competing forward and reverse rates of reaction

These studies suggest that, as science teachers, we spontaneously use analogies to help pupils understand. Similar observations were made by Treagust et al (1992). They showed that science teachers used analogies extensively but with little advance preparation or introducing after explaining the target idea. They recognised that opportunities for pupil understanding were limited as teachers often did not fully explain the analogy being used. A more systematic and planned use of models in teaching may provide significant help to pupils in grasping concepts. Raghavan and Glaser (1995) showed that by making models a central feature of the learning process, pupils were able to show high levels of conceptual understanding. The project, called Model-based Analysis and Reasoning in Science (MARS) was an attempt to 'create an environment conducive to fostering conceptual understanding and reasoning about scientific phenomena'. This qualitative reasoning by use of models 'concretised' abstract ideas and gave pupils a greater cognitive understanding, not only of the idea, but also the processes and reasoning by which the concept was modelled. Importantly, they also noted that previous underachievers participated with greater positive contribution. More recent studies have confirmed the learning gains which can be achieved by making models, modelling and evaluation of models central to the learning process (e.g. Tregidgo & Ratcliffe, 2000; Erduran, 2000).

Erduran's study highlights the abilities of 11-13 year old pupils in discussing important aspects of chemical models which are not present in teachers' explanations about the models. For example pupils could discuss the boundaries of a model – its applicability to a new chemical concept – a feature lacking in some teachers' explanations.

The importance, then, of illustrating the strengths and limitations of models cannot be underestimated.

Grosslight et al (1991) show that learners' and experts' views of models differ (table 1).

Table 1 Learners' and experts' views of models

Learners' Views	Experts' views
Models are physical or visual in nature	There are both physical and abstract models
They show or help communicate about real things	Models help us to understand or think about phenomena
	The validity of a model can be tested by comparing its implications to observations and measurements in the real world
Different models of the same thing show literally different aspects of real things	Different models of the same phenomenon can be built to accommodate different purposes
Scientific models can change if they are made wrong or new information is found	Scientific models can be replaced by better ones

From this they suggest that we should provide pupils with a range of activities to take their understanding from 'level 1' to level 3':
Level 1: Models are simply copies of reality
Level 2: There is a specific, explicit purpose which affects the way a model is constructed. It no longer must exactly correspond with the real world object or event.
Level 3: Models are constructed for developing and testing ideas. The modeller takes an active role in construction. Models are manipulated and subject to tests.

Grosslight et al (1991) suggest some activities which might help pupils develop their understanding of models and of the target concepts. This includes providing learners with experience of using models to solve problems. The model can then become a tool of enquiry and not a package of facts. Another strategy is to provide multiple models of the same phenomenon. This can be helpful as concepts, such as atoms and molecules, are refined with increasing experience of their use.

Harrison and Treagust (1996) highlight what happens when models are not used carefully in explaining chemical phenomena. In studying pupils' mental models of atoms and molecules, they found such misconceptions as: atoms grow and reproduce and atomic nuclei divide; electron shells are visualised as shells that enclose and protect atoms, while electron clouds are structures in which electrons are embedded. They attribute some of these misconceptions to inadequate explanation and exploration of the models presented by the teacher. They argue that analogical models are an intrinsic part of chemical understanding and suggest that student understanding may break down when models are used 'because the students often do not recognise that the explanation or process they are using is a model and, consequently, they mistake the model for reality'. They make two recommendations from this detailed study:
Students should be given time to develop modelling skills, including using models to explain ideas and recognising the strengths and limitations of particular models;

Whenever an analogy or model is used, 'teachers should consciously ensure that the analogy is familiar and that they make the effort to identify both the shared and unshared attributes with the students'.

Recommendations for practice

Taken together, the research evidence discussed suggests the following as being effective in helping pupils understand chemical concepts and models as an important aspect of developing and explaining ideas:

I. Use models at the beginning of a topic (Sizmur & Ashby, 1997) or integrated fully into the teaching of key ideas.

II. Where analogies are used, check pupils' understanding of the analogy itself before using it to explain the key idea.

III. Show the similarities and differences of the model to the target idea – i.e. highlight the strengths and limitations of the model.

IV. Give pupils practice in developing their own models and use them to explain ideas. Highlight the strengths and limitations of their models

V. Encourage pupils to explore the use of (their) models in explaining related ideas – does the model still hold?

VI. When using concrete models (e.g. drawings/ 3D models of atoms, bonding etc), 3D models seem to lead to greater understanding and retention of key ideas compared to 2D.

VII. Enjoy using models – they provide an interesting, visual and stimulating way of understanding chemical ideas! Models can really help and motivate low achieving pupils.

References:

Erduran S (2000) Designing learning environments to nurture growth of chemical knowledge through modelling *Paper presented at Modelling in Chemical Education Conference University of Reading, March 2000*

Gilbert J K (ed) (1994) *Models and modelling in science education*. Hatfield ASE

Gilbert J K (1998) Explaining with models In Ratcliffe, M (ed) *ASE Guide to Secondary Science Education.* Cheltenham, Stanley Thornes pp159-166

Grosslight L., Unger, C., Jay, E., and Smith, C. (1991) Understanding models and their use in science conceptions of middle and high school students and experts. *Journal of Research in Science Teaching* 28, 9, 799-822

Jarman R (1996) Student teachers' use of analogies in science instruction *International Journal of Science Education* 18, 7, 869-880

Harrison, A.G. & Treagust, D. (1996) Secondary students' mental models of atoms and molecules: Implications for teaching chemistry *Science Education* 80, 5, 509-534

Mayer, R E (1989) Models for understanding. *Review of Educational Research* 59, 1, 43-64

Sizmur, S & Ashby, J (1997) *Introducing scientific concepts to children – research summary* Slough: NFER

Thiele, R B & Treagust D F (1994) An interpretive examination of high school chemistry teachers' analogical explanations *Journal of Research in Science Teaching* 31, 3, 227-242

Treagust, D., Duit, R., Joslin, P., & Lindauer, I (1992) Science teachers' use of analogies: observations from classroom practice *International Journal of Science Education* 14, 4, 413-422

Tregidgo D & Ratcliffe M (2000) The use of modelling for improving pupils' learning about cells *School Science Review* 81, 296, 53-59

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