Lesson 1 Thought experiments

There are 5 activities. Pupils work on each of these in pairs, each recording an answer in their answer book.

These activities will take about 30 minutes. Get the pupils give their own answers following a brief paired discussion. Explain to the pupils that they'll be returning to these questions over the next couple of lessons.

The purpose of the activities
Pupils have already been introduced to a simple particle model of matter at KS3. The thought experiments are *formative assessment activities*: they are designed to give the teacher some insight into the extent to which pupils can use this particle model to explain simple physical and chemical change processes.

Specific notes are provided for each activity. For some of the activities, it is suggested that you give some additional explanation about the question.

Marking the work
The purpose activity is formative assessment. The pupils' answers will inform your teaching about modelling change with a simple particle model. Some of the thought experiments appear during later teaching. We therefore suggest that you look at the group's work and note down recurring features in their reasoning that you'll need to address in the teaching. Specific suggestions about what to look for are provided for each activity.

How the work is followed up in the unit
Several of the thought experiments are built upon during teaching. Furthermore, some appear in the unit post-test.

<u>Homework activity</u>
- At the end of the lesson, show the students some water that is slowly boiling.
- Ask the question: 'What is in the bubbles that are forming?' Most students will say air. Keep a record of the answers that are given - conduct a vote.
- Ask the students to ask their parents what is in the bubbles in boiling water.
- Ask the students to leave a glass of tap water in a room for about $^{3}/_{4}$ hour and note what they observe.

This will be followed up at the beginning of the next lesson.

Weighing air - thought experiment

The purpose of this activity
The 'weighing air' activity is designed to provide the teacher with information about how pupils expect gases to behave, and how they model gases in terms of particles.

What pupils tend to say
- *The mass of gases*. Some pupils are likely to say that air has no mass (and therefore will not affect the position of the balance beam). Gases do not seem to be thought of as matter in the same way that solids and liquids are for some pupils. Other pupils may say that air has negative mass (and therefore will make the side of the beam with the can with extra air in it go upwards). These pupils may not distinguish *mass* and *density*, noting that adding air to certain things makes them float.
- *Modelling with particles*. Some KS3 pupils may not think of gases as being made of particles at all. Others may label 'air' as being the stuff that is in between the particles! Some may draw particles of different sizes in the two cans.

Additional information to be given about the question.
Some pupils do not easily understand how balance beams work. It is probably wise to run through this briefly. Make sure that pupils have labelled where the air is.

Issues likely to come up as you look at the work, to be addressed in later teaching
- What is in between the particles, especially in gases?
- How can gases have mass?

How this activity is followed up in the unit
Pupils will get a second chance to have a go at this question after you have gone through the particle model again. The question also appears on the unit test.

Dissolving - thought experiment

The purpose of this activity
The 'dissolving' activity is designed to provide the teacher with information about how pupils explain mass changes on dissolving, and how they model dissolving in terms of particles.

What pupils tend to say
- *The mass of the solution*. Some pupils are likely to say that side A (with the solution) is heavier because they are not considering the mass of the container from which the sugar was poured. Others say that side A is heavier because the sugar has 'soaked up' the water. The issue here is that pupils are not focusing on the appropriate features of the system. Many pupils will say that side A (with the solution) is lighter, reasoning that particles of sugar 'float' in the water in a solution and therefore have reduced mass. This pattern of reasoning may be common amongst pupils who model dissolving in terms of particles; pupils who do *not* readily think in terms of particles are likely to get the correct answer (the mass will remain constant) on the grounds that nothing has been added or removed.
- *Modelling with particles*. Pupils may not be clear about how solute and solvent particles are distributed in a solution. Pupils may draw sugar particles differently when in aqueous solution, compared to in the solid state.

Additional information to be given about the question
Encourage pupils to explain any differences between the particles that they have drawn in each container as fully as possible.

Issues likely to come up as you look at the work, to be addressed in later teaching
- How are particles distributed in a solution?
- How come particles that 'float' have the same mass?
- How should particles in a liquid be drawn in diagrams? Should they be touching? How can we differentiate solids and liquids in our diagrams?

How this activity is followed up in the unit
Pupils will get a second chance to have a go at this question after you have gone through the particle model again. The question also appears on the unit test.

Magnesium ribbon - thought experiment

The purpose of this activity
The 'magnesium ribbon' activity is designed to provide the teacher with information about how pupils think about chemical change, how they think about mass change on combustion, and how they model combustion in terms of particles. It is a complex process to model as the chemical reaction involves a state change (gaseous oxygen reacts to form solid magnesium oxide).

What pupils tend to say
- *The mass of gases and powders.* Some pupils may say that gases make things lighter. Many may say that gases or 'steam' are released when the iron wool is burnt, making it lighter. Many pupils may think that 'powders' are lighter than 'solids', not recognising that powders *are* solids.
- *The nature of chemical change.* Many pupils may not describe combustion in terms of a recombination of particles in the iron wool and particles in the air. They may not be clear where the white powder has come from.

Additional information to be given about the question
None.

Issues likely to come up as you look at the work, to be addressed in later teaching
- Do the pupils model chemical change in terms of a re-arrangement of particles?
- Do pupils assume that 'gas particles' have mass?

How this activity is followed up in the unit
This question is explained in the teaching, and appears on the unit test.

Mixing liquids - thought experiment

The purpose of this activity
The 'mixing liquids' activity is designed to provide the teacher with information about how pupils model the structure of substances in terms of their ideas about particles.

What pupils tend to say
- The mass must be less after mixing as the volume is less (i.e. mass and density are not differentiated).
- No clear idea how the particles might be spaced to give a decrease in volume. [We would not expect pupils to know this unless it had been taught explicitly.]

Additional information about the question
We have not written this question to include information about how the weighing was done. Make sure that pupils are clear that the question is referring to *the mass of the 2 measuring cylinders plus contents, before and after mixing.*

Issues likely to come up as you look at the work, to be addressed in later teaching
- Do the pupils assume that the particles themselves change on mixing?

How this activity is followed up in the unit
Pupils have a second opportunity to attempt this question during the teaching unit.

Iron bar - thought experiment

The purpose of this activity
The 'iron bar' activity is designed to provide the teacher with information about how pupils model the structure of substances in terms of their ideas about particles.

What pupils tend to say
- The particles themselves expand.
- The bar gets heavier. Bigger particles are heavier. Size is proportional to mass.

Additional information about this question
None.

Issues likely to come up as you look at the work, to be addressed in later teaching
- Do the pupils assume that the particles themselves change on heating?
- Do pupils assume that *size* and *mass* are proportional? Do they recognise the difference between *mass* and *density*?

How this activity is followed up in the unit
This activity is used as an example of how we model change processes in terms of a simple particle model. Other examples of expansions are included in the teaching scheme.

Lesson 2 Teaching about modelling with particles

Purpose of the lesson

The purpose of this lesson is to teach pupils how to model various change processes in terms of the simple particle model of matter commonly introduced at KS3, and to revise/reinforce key features of that model. Insights into pupils' current thinking gained from the 'Thought experiments' will inform the teaching approach adopted, and it will be appropriate to emphasise different things with different classes.

Sequence of the lesson

- Teacher presentation: modelling change in terms of a simple particle model. (Summary sheet for pupils: the particle model).
- Discussion of homework activity on bubbles in boiling water.
- Examples of modelling by the teacher: 4 demonstrations (Magnesium ribbon, precipitation, iron bar, and Cartesian diver).

Teacher presentation

Key features of the particle model introduced at KS3 are:

Feature	*Notes*
<u>Matter is made of particles</u> • All matter is made entirely of particles. • Individual particles are too small to be seen. • We can think of particles as being like hard, tiny balls that do not change. They are usually drawn as dots or small circles. • There is nothing in between the particles.	This model does not provide any mechanism for bonding between particles in solids, or attractions between particles in liquids.
<u>The motion of particles</u> • The particles are in constant motion. • As you heat particles, they move more and as you cool them they move less.	This aspect of the model is used to explain phase changes on heating. Pupils at KS3 (and, indeed, beyond) are likely to have misconceptions about *why* the particles are in constant motion, though teachers may judge that these misconceptions are better dealt with at a later stage.
<u>The distribution of particles</u> • In solids and liquids the particles are packed so closely that they are touching. • In solids the particles are arranged in regular patterns. Each vibrates in a fixed position. • In liquids the particles are arranged irregularly and move from place to place by 'rolling over' each other.	This explains the relative elasticity of solids, liquids and gases, and the big discrepancies in density between solids and liquids compared to gases. Teachers may judge that the issue of gravity does not need to be treated explicitly at KS3, though pupils may refer to the effect of gravity on the particles.

• In gases, the empty space between the particles is much larger than the space occupied by the particles themselves. • Particles of a gas in an enclosed space are evenly distributed (because gravity has a negligible effect on them).	
Attractions between particles • Any two particles are attracted to each other, but the size of this attraction decreases rapidly with distance. • In a gas the attraction is negligible, except at high pressure and at low temperature when it may cause a gas to condense to a liquid.	This aspect of the model is often not dealt with at KS3, with the result that pupils are not presented with a mechanism for bonding in solids, or attractions between particles in liquids. The notion of *attraction* between particles goes some way to explaining bonding without referring to electrons. If inter- and intramolecular forces are modelled like this, it will be necessary to differentiate the different mechanisms at KS4 in terms of electrons. It is not possible to differentiate physical and chemical change in terms of the particle model used at KS3.
Similarities and differences between particles • There are 100 or so fundamental particles, called atoms. • Different substances consist of different particles, but all particles of one substance are identical. • A mixture consists of particles of 2 or more different kinds. • A chemical reaction is a re-arrangement of atoms.	The term 'particle' is used for both atoms and molecules. This use of the word makes it difficult to differentiate the structure of atomic, ionic or molecular giant structures from simple atomic and simple molecular structures.

A pupil sheet summarising the model is available.

The lesson begins with a teacher presentation of this model and how it is used to model some familiar change processes. It will probably be necessary to explain to the class what is meant by a *model*, and what is involved in *modelling* change processes. An approach to doing this is suggested on the pupil sheet.

***Discussion of homework**: bubbles in boiling water*

The bubbles that come out of tap water left to stand are dissolved gases (mainly oxygen). The bubbles in boiling water are *steam* - that is, water in the gas phase. This phase change can be modelled for pupils in terms of the simple particle model that has just been developed.

If desired, you can demonstrate to pupils that the bubbles in boiling water are not air by trying to collect the ‘air’ given off over water.

Examples of modelling by the teacher

Ideas for 4 demonstrations are provided which involve *modelling* change processes in terms of a simple particle model.

The combustion of magnesium ribbon as an example of chemical change

Pupils met this example as a ‘Thought experiment’.

Depending on the group and the timing it might be appropriate to demonstrate this reaction on a mass balance.

Notes on the demonstration
Equipment needed:

- Approximately 50cm of magnesium ribbon
- Crucible
- Crucible tongs
- Bunsen
- Heatproof mat
- Mass balance

In order to show the increase in mass from the reaction you will need to burn about 0.5g of magnesium (approximately 50cm of magnesium ribbon).
The balance should be sensitive to 0.01 g to show the mass change.
Place the magnesium ribbon and crucible on the balance and tare the balance.
Burn the magnesium and re-weight the crucible to show the mass gain.

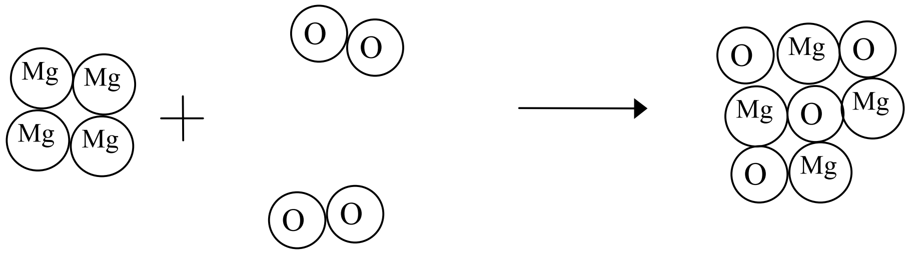
It should be noted that the amount of magnesium used is considerably more than normal pupil experiments and will burn for longer. The danger of damage to the eyes from looking directly at the reaction should be stressed.

Go through the ‘Thought experiment’ on magnesium ribbon in order to teach pupils how to model chemical change processes using the particle model that has been developed/revised. Key features to emphasise:

- Burning in air results in a *combustion* reaction. Combustion involves chemical combination with oxygen.
- The white powder is magnesium oxide. All the magnesium atoms in the magnesium ribbon are still contained in the magnesium oxide. They are chemically bonded to oxygen atoms that were originally in the air.
- The mass of the magnesium oxide is therefore greater than the mass of the magnesium ribbon.
- Some pupils are likely to struggle with the idea that gases can make things heavier. Modelling in terms of atoms may help such pupils to appreciate why metal oxides are heavier than the original reacting mass of metal. Pupils may also need help in understanding the difference between the *mass* of a gas and its *density*. The low

density of gases may result in pupils arguing that gases make things *lighter*. One possible way into this issue for pupils is through the old 'trick' question, "which is heavier, a kilo of feathers or a kilo of lead?" The point needing to be made here is that even though a gas has a low density, if particles of a gas are combined chemically with particles of a metal the overall mass will increase.

- Pupils will need to be presented with some kind of symbolic representation of the particles in magnesium, and in magnesium oxide. Magnesium has been chosen for this example to allow teachers to avoid issues of stoichiometry. When using representations such as the following, it is important to make clear the difference between lattice structures (i.e. Mg and MgO), and simple molecular structures (i.e. O_2):



Precipitation

This example is new to pupils. It provides an opportunity for the teacher to allow pupils to attempt to model another chemical change process involving a change of state, following the teacher's explanation of the combustion of magnesium.

Depending on the group and the timing it might be appropriate to demonstrate this reaction on a mass balance.

A good precipitation reaction can be achieved by mixing a solution of a soluble silver salt

(such as $AgNO_3$) with a solution of a soluble halide (such as KI).

Notes on the demonstration

Equipment:

- 0.1M Silver nitrate solution
- 0.1M Potassium iodide solution
- 2 small measuring cylinders
- 2 small beakers
- Mass balance

Measure $10 cm^3$ of each reagent into a small beaker.
Place both beakers on the mass balance. If possible the balance should be set to be sensitive to only 0.1g.
Tare the balance, mix the reagents and leave both beakers on the balance.
There should be no change in mass.

Many of the issues relevant to the combustion example are also relevant to this example. Other features to emphasise:

- Atoms are conserved, therefore mass is conserved.
- Pupils may need help in recognising the difference between the *density* of substances, and the *mass* of substances. They may assume that solids have a greater *mass* than liquids.
- How a solid arises from a reaction between liquids might need to be addressed.

Iron bar

Pupils met this example as a 'thought experiment'.

Go through the 'Thought experiment' about the iron bar in order to teach pupils how to model the process of expansion on heating using the particle model that has been developed/revised. Key features to emphasise:

- The expansion of the iron bar is due to changes in the motion of the particles of iron. As they are heated, they vibrate more with the effect that the distance between them changes.

- The particles themselves do not change.

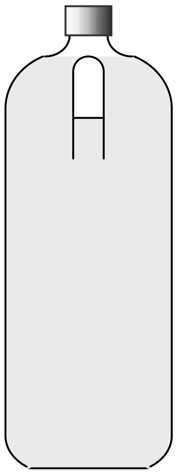
- Pupils may see inconsistencies between the explanation given for the expansion of solids on heating, and the statement that the particles are touching in both solids and liquids on the pupil sheet. It may be necessary to explain this by saying that, due to the motion of the particles at a given temperature, neither solids nor liquids are *compressible*. We therefore think of the particles as *touching*.

- Explain the conservation of mass by saying that the particles themselves have not changed, only the spacing between them.

Cartesian Diver

This context is new to pupils. It is an enjoyable demonstration that allows them to model a fairly complex phenomenon in terms of the simple particle model.

Preparation: -



Use a sample tube part filled with water and a clear plastic 'pop' bottle.

Some trial and error is needed to get the amount of water in the sample tube right so the tube just floats.

Check the diver to see if it sinks in the sealed plastic bottle full of water when you squeeze it.

Label the bottle with a ‘true’ and ‘false label’ at the top and the bottom of the bottle.

Dress the bottle up a bit and cover the lid with tin foil.

The demonstration:
An entertaining way to introduce the 'diver' is to use it as a 'lie detector'. By squeezing and releasing the bottle the 'diver' can be made to move to either the true or false labels. Have a student to place their fingers on the foiled top and ask them questions. Start with their name (which is obviously true) and then try more amusing questions e.g. "do you fancy Joe Bloggs?"

Key questions to ask:
Ask if they can work out what you are doing to make the diver sink and float?

Squeezing the bottle makes it sink. What property makes things sink or float in water?

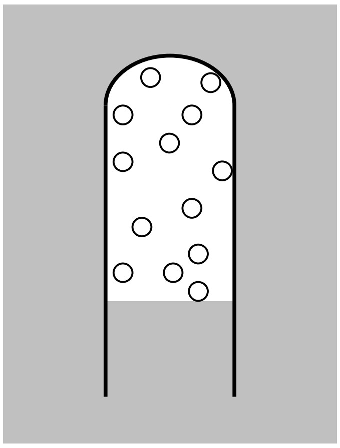
If the diver is more dense than the water what will happen?

If the diver is less dense than water what will happen?

So how does squeezing the bottle make the diver more dense?
(Look closely at the volume of air in the diver as it rises and falls.)

How can the particle model explain the actions of the diver?

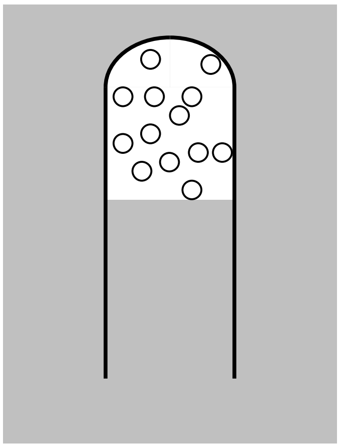
Fig 1



Before squeezing the bottle how spaced out do you think the air particles are in the lid of the diver?

If they are spread out and it floats, is the overall density of the diver greater of less than the density of the water?

Fig 2



In the 'lie detector', there are air particles and water particles. Which particles are spread out with space between? Which particles are close together, touching each other?

If the air particles are spread out and the water particles are close together, which particles will it be possible to push closer together?

If the air particles are pushed closer together by squeezing the bottle, what do you think will happen to the volume that the air will occupy, will it increase or decrease?

If the volume decreases what will happen to the level of the water in the diver, will it go up or down?

So if the particles of air are squashed closer together, what happens to the density of the air in the diver?

If the air in the diver is denser, what about the density of the diver (overall) compared to before the bottle was squashed?

Lesson 3 Modelling tasks

Purpose of the lesson
The purpose of this lesson is for pupils to apply what they learnt in the last lesson about how to model change processes in terms of the simple particle model. The pupils are presented with the same 'thought experiments' as in lesson 1. They are asked to model what is happening in each experiment, using their knowledge of the particle model.

Sequence of the lesson

- Recap on the particle model presented last lesson.

- Pupils carry out their own modelling tasks (weighing air, dissolving, exhaust, mixing liquids). For this task pupils should use the student reference sheet.

  Some of the modelling tasks are the same contexts as the thought experiments. It should be made clear to pupils that they are not just repeat tasks, that they should use what they have learnt about the particle model to complete the modelling tasks.

- Review the key features of the models in terms of the particle model.

The core of this lesson should take about 30 minutes. If the Cartesian diver presentation from lesson was used to generate a homework exercise, it would be appropriate to revisit this at the end of this lesson.

Modelling change Notes for the teacher 3A

Magnesium ribbon - modelling task

During this part of the teaching, the teacher's role is to help pupils to model what's going on in terms of particles, by asking closely targeted, closed questions, and by reminding pupils of relevant aspects of the teaching in Part 2. For example:

- What did we say would happen to the mass, if you add gas particles?
- How did we decide to draw the particles in a gas? Where is the gas, and where are the particles?

Modelling change Notes for the teacher 3B

Dissolving - modelling task

During this part of the teaching, the teacher's role is to help pupils to model what's going on in terms of particles, by asking closely targeted, closed questions, and by reminding pupils of relevant aspects of the teaching in Part 2. For example:

- What did we say would happen to the mass, when the sugar and water particles were mixed?
- How should we draw the particles in the sugar solution? How about the water particles? How about the particles in the crystals of sugar?
-

Modelling change Notes for the teacher 3C

Exhaust - modelling task

During this part of the teaching, the teacher's role is to help pupils to model what's going on in terms of particles, by asking closely targeted, closed questions, and by reminding pupils of relevant aspects of the teaching in Part 2. For example:

- How can we model what happens when the petrol burns in air?
- How can the gas be heavier than the petrol?

Modelling change Notes for the teacher 3D

Mixing liquids - modelling task

During this part of the teaching, the teacher's role is to help pupils to model what's going on in terms of particles, by asking closely targeted, closed questions, and by reminding pupils of relevant aspects of earlier teaching. For example:

- What did we say would happen to the mass, when the liquids were mixed?
- How should we draw the particles before and after mixing?

Lesson 4 Testing

There are 7 test questions. The ideas being investigated in the test are as follows:

Weighing air	This question deals with pupils' understanding of the properties of gases, and how these can be modelled in terms of particles. It appeared as a 'thought experiment'. The pupils' responses will allow you to compare their thinking after teaching to their starting points.
Dissolving	This question addresses the process of dissolving (a physical change). It appeared as a 'thought experiment'. The pupils' responses will allow you to compare their thinking after teaching to their starting points.
Magnesium ribbon	This question addresses the process of combustion (a chemical change). It appeared as a 'thought experiment'. The pupils' responses will allow you to compare their thinking after teaching to their starting points.
Dissolving rock	This question addresses a chemical change involving a change of state. The context has not been used in the teaching. It will allow you to judge how successfully pupils are able to transfer the ideas that you have been developing about modelling to unfamiliar contexts.
Blue liquid	This question addresses expansion (a physical change). The context is unfamiliar to pupils, though they have seen an explanation of the expansion of metals in terms of particles. It will allow you to judge how successfully pupils are able to transfer the ideas that you have been developing about modelling to unfamiliar contexts.
Rotting apple	This question addresses a chemical change (decay) involving a change of state (solid carbohydrates are oxidised to carbon dioxide gas and water). The context is unfamiliar to pupils - and complex. It will allow you to judge how successfully pupils are able to transfer the ideas that you have been developing about modelling to unfamiliar, complex contexts.
Air in a flask	This question addresses how gases are modelled in terms of particles.

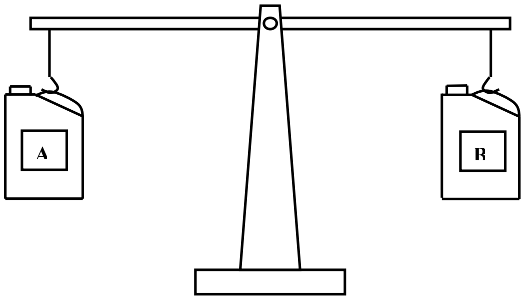
Name:

Thought Experiment 1: Weighing Air

Daniel, Inderjit and Michael are weighing some metal petrol cans.
They are using a balance beam.

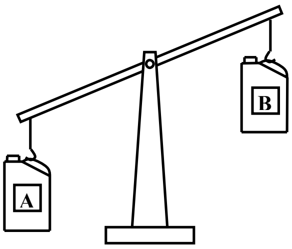
The balance beam is level.

This means that **‘A’ and ‘B’ have the same mass**.

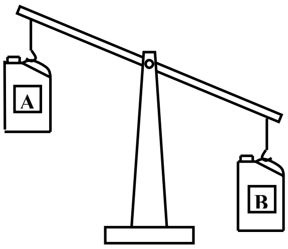


Next, they use a bicycle pump to pump some extra air into can B.

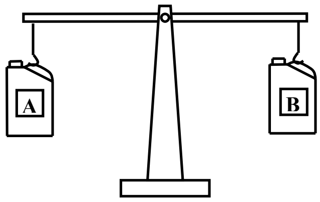
Daniel says: The extra air in B will make it **lighter**, so it will go **upwards**.



Inderjit says: The extra air in B will make it **heavier**, so it will go **downwards**.



Michael says: The extra air will make **no difference** to the mass of the cans, so the balance beam will **stay level**.



Discuss this thought experiment with your partner.

Which of the boys do you think is right?

What would you say to convince the other two boys that your answer is correct? Give as much detail as you can!

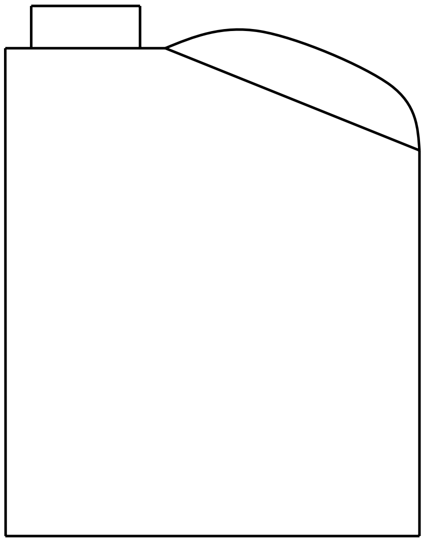
Name:

Imagine that you could see the air in Can A and Can B. Fill in the diagrams below to show what the air is like.

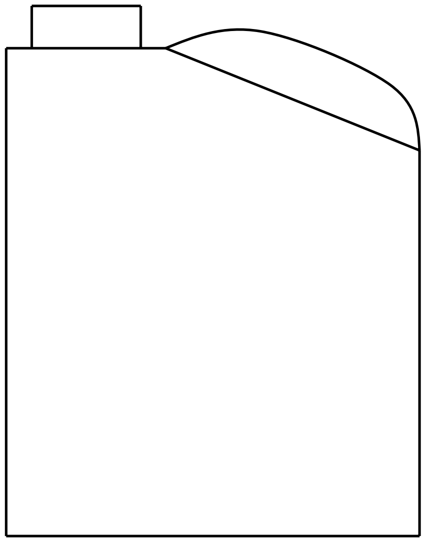
Label the air.

Write some notes to help us to understand your diagram.

Can A*:* no extra air has been added



Can B*:* extra air has been added



Explanation:

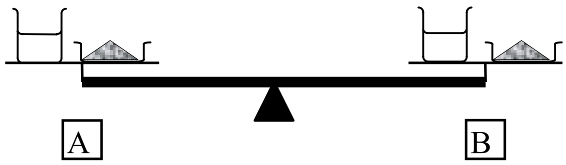
Name:

Thought Experiment 2: Dissolving

Sonia, Lisa and Hadia are weighing sugar and water.

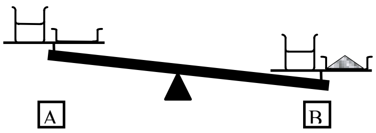
The balance beam is level.

This means that ‘A’ and ‘B’ **have the same mass**.

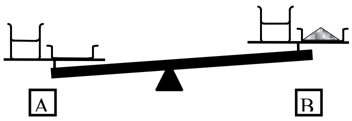


Next, they mix the sugar and water on side A. The sugar can no longer be seen.

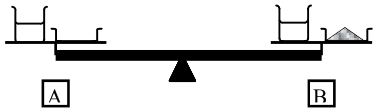
Sonia says: Side A will be **lighter**.



Lisa says: Side A will be **heavier**.



Hadia says: Sides A and B will have **the same mass**.



Discuss this thought experiment with your partner.

Which of the girls do you think is right?

What would you say to convince the other two girls that your answer is correct? Give as much detail as you can!

Name:

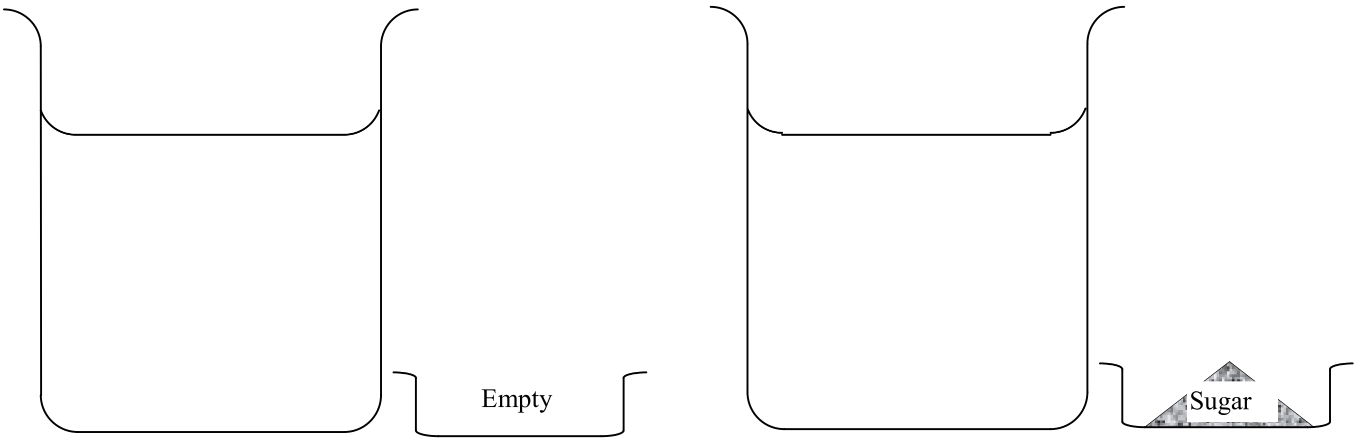
Imagine that you can see inside the liquid on each side of the balance.

Fill in the diagrams below to show what the liquid is like.

Write some notes to help us to understand your diagram. Explain any differences between the diagrams as fully as you can.

A: the sugar and water are mixed

B: the water is on its own

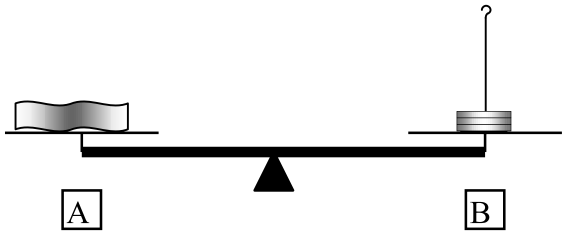


Explanation:

Name:

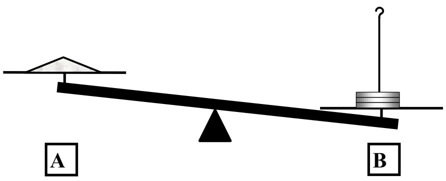
Thought Experiment 3: Magnesium ribbon

Fiona, Alison and Louise are doing some burning and weighing work. A small amount of magnesium ribbon was placed on side 'A', and weights were added to side 'B' to balance the scales.

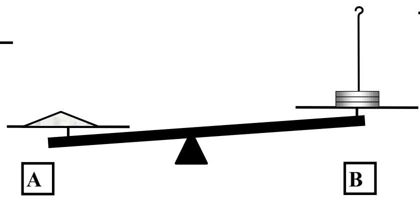


The magnesium ribbon was then removed and heated in air. It formed a white powder, which was carefully collected and returned to side 'A'.

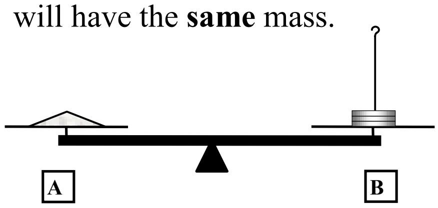
Fiona says: Side A will be **lighter**.



Alison says: Side A will be **heavier**.



Louise says: Sides A and B will have the **same** mass.



Discuss this thought experiment with your partner.

Which of the girls do you think is right?

What would you say to convince the other two girls that your answer is correct? Give as much detail as you can!

Name:

Imagine that you can see inside the magnesium ribbon before it was burnt in air, and the white powder that was collected.

Fill in the diagrams below to show what the substances are like.

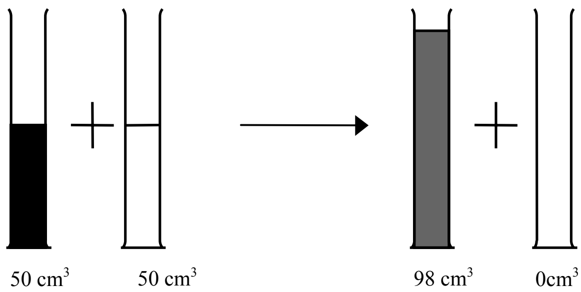
Write some notes to help us to understand your diagram.

A: The magnesium ribbon and air **before** burning	B: The white powder that was collected **after** burning

Explanation:

Thought Experiment 4: Mixing liquids

Robert, Kamran and Ian are experimenting with liquids. They have put 50 cm^3 of two different liquids into measuring cylinders. When they mix the liquids, they expect the total volume to be 100 cm^3. However, even though they are careful not to spill anything when they mix the liquids they are surprised to see that the total volume is only 98cm^3.



Robert says:
I think the mass of the cylinders and the liquid will be **the same** after mixing.

Kamran says:
I think that the mass of the cylinders and the liquid will be **lighter** after mixing.

Ian says:
I think the mass of the cylinders and the liquid will be **heavier** after mixing.

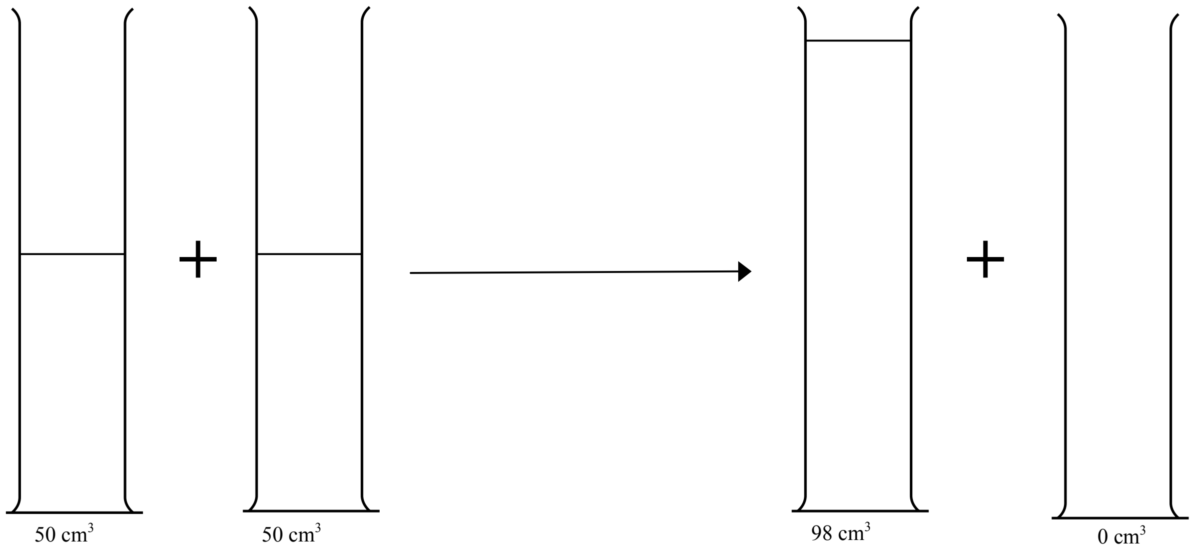
Discuss this thought experiment with your partner.

Which of the boys do you think is right?

What would you say to convince the other two boys that your answer is correct? Give as much detail as you can!

Name:

Imagine that you can see the structure of the liquids inside, before and after mixing.
Draw on to the diagram below how you imagine the structure of the liquids:



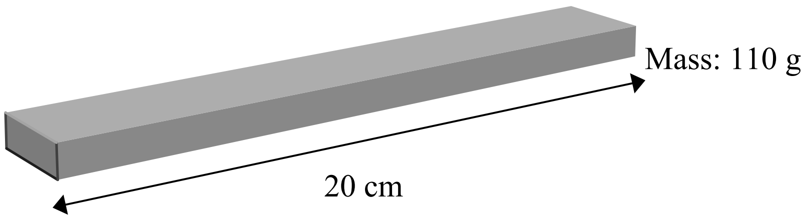
Explanation:

Name:

Modelling change student sheet 1D page 1

Thought Experiment 5: Iron bar

A teacher shows her class a metal bar that is **20cm long** and has a **mass of 110g**.



The teacher **heats** the metal bar in a Bunsen flame with some tongs for a few minutes. When she measured the **hot** metal bar it was **20.3cm long**. She asked the class what they thought had happened to the **mass** of the bar.

Anna said: the mass of the bar would **increase** because the bar is bigger now.

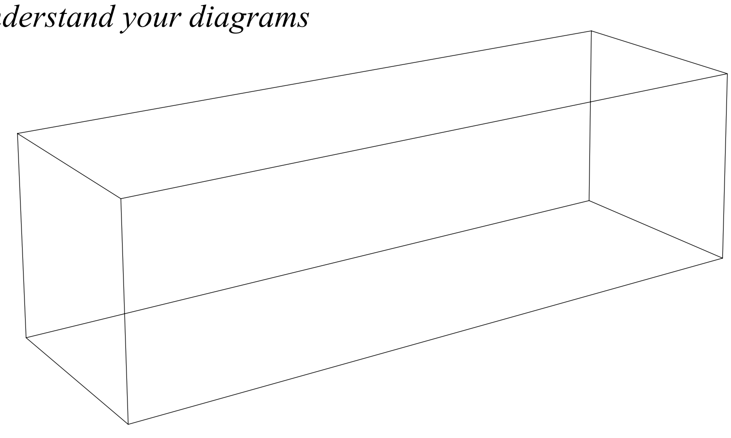
Zoë said: the mass of the bar would **stay the same**.

Which of the girls do you think is right?

What would you say to convince the class that your answer is correct?
Give as much detail as you can.

Imagine that you can see the structure of the metal bar, inside. Fill in the diagrams below to show what the metal is like.

Write some notes to help us to understand your diagrams



Name:

Modelling change student reference sheet 2A

In science, we explain the properties and behaviour of matter in terms of the particle model of matter

Particle model of matter
All matter is made entirely of particles.
Individual particles are too small to be seen.
We can think of particles as being like hard, tiny balls that do not change. They are usually drawn as dots or small circles.
There is nothing in between the particles.
There are 100 or so fundamental particles, called atoms.
Different substances consist of different particles, but all particles of one substance are identical.
A mixture consists of particles of 2 or more different kinds.
A chemical reaction is a re-arrangement of atoms.

Properties and behaviour of matter
Solids are hard.
Liquids stay in the bottom of the container, but gases spread to fill the container.
Metals expand when heated.
When you burn magnesium in oxygen, you form magnesium oxide.
Copper carbonate is green but copper oxide is white.

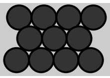
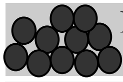
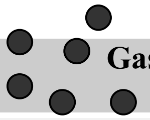
Name:

Modelling change student reference sheet 2B

Modelling the properties and behaviour of matter

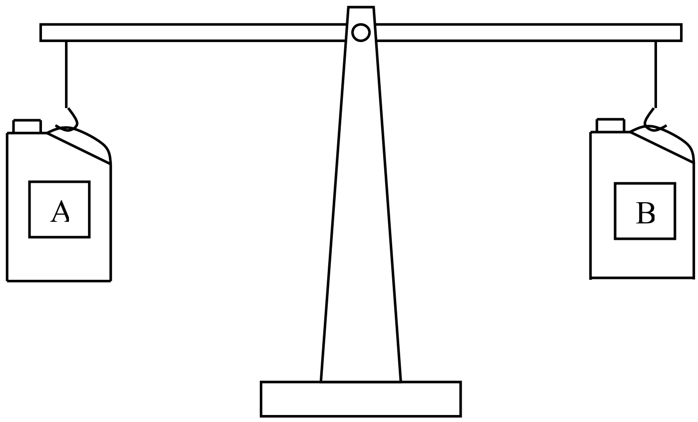
This table will give you useful clues to help with the tasks in this topic.

Refer to it when your teacher asks you to explain something using ideas about particles.

	 **Solids**	 **Liquids**	 **Gases**
How the particles are arranged	The particles are packed so close that they are touching.	The particles are packed so close that they are touching.	The particles are very spread out so that the empty space between the particles is much larger than the space occupied by the particles themselves.
The Bonds between particles	The particles are so close that they are attracted to each other. They are held together by STRONG BONDS.	The particles are so close that they are attracted to each other. The particles in liquids therefore stay touching each other at the bottom of their container. They are NOT held together by strong bonds.	In gases, the particles are so spaced out so that there is almost no attraction between them. Particles of a gas in an enclosed space are evenly distributed.
The motion of the particles	The particles are in constant motion, vibrating on the spot.	The particles are in constant motion, rolling over each other.	The particles are in constant motion, sometimes colliding with each other, or with the walls of the container.
The effect of heat on the particles	As you heat solids, the particles vibrate more and as you cool solids the particles vibrate less. This explains why solids expand when they are heated and contract when they are cooled.	As you heat liquids, the particles move more and as you cool liquids the particles move less. This explains why liquids expand when they are heated and contract when they are cooled.	As you heat gases, the particles move more and as you cool liquids the particles move less.

Name:

Modelling task 1: Weighing air



Daniel, Inderjit and Michael are weighing some metal petrol cans.

They are using a balance beam.

The balance beam is level.

This means that **'A' and 'B' have the same mass**.

Next, they use a bicycle pump to pump some extra air into can B.

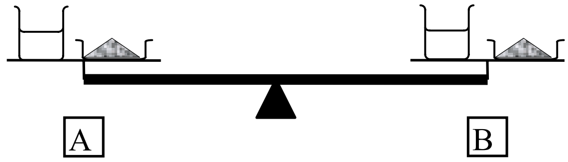
Model, using words and pictures, what happens to Can B when extra air is added.

Name:

Modelling change student sheet 3B

Modelling task 2: Dissolving

Sonia, Lisa and Hadia are weighing sugar and water.



The balance beam is level.

This means that **'A' and 'B' have the same mass.**

Next, they mix the sugar and water on side A. The sugar can no longer be seen.

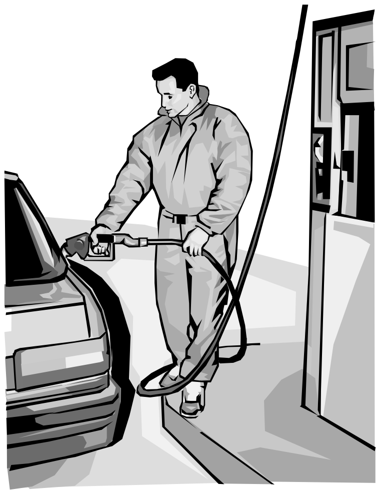
Model, using words and pictures, what happens in the beaker when the sugar and water are mixed. What effect does this have on the balance beam? Explain your answer!

Name:

Modelling task 3: Exhaust

Eric has completely run out of petrol.
He fills his car with petrol.

The petrol weighs 10kg



Model, using words and pictures, what happens to the petrol as it burns in air inside the car's engine.

When all the petrol is burnt, will the exhaust gases,

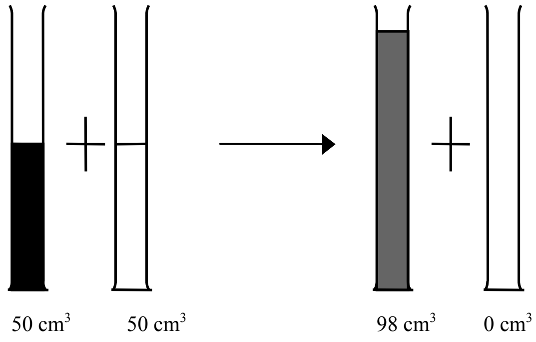
weigh **more** than 10kg?	
weigh **less** than 10kg?	
weigh **exactly** 10kg?	

Name:

Modelling change student sheet 3D

Modelling task 4: Mixing liquids

Robert, Kamran and Ian are experimenting with liquids. They have put 50 cm^3 of two different liquids into measuring cylinders. When they mix the liquids, they expect the total volume to be 100 cm^3. However, even though they are careful not to spill anything when they mix the liquids they are surprised to see that the total volume is only 98cm^3.



Robert says: I think the mass of the cylinders and the liquid will be **the same** after mixing.

Kamran says: I think that the mass of the cylinders and the liquid will be **lighter** after mixing.

Ian says: I think the mass of the cylinders and the liquid will be **heavier** after mixing.

What do you think will happen?

Model, using words and pictures, what happens when the liquids are mixed.

Name:

Modelling change student sheet 4A

Test question 1: Weighing air

Daniel, Inderjit and Michael are weighing some metal petrol cans.

They are using a balance beam.

The balance beam is level.

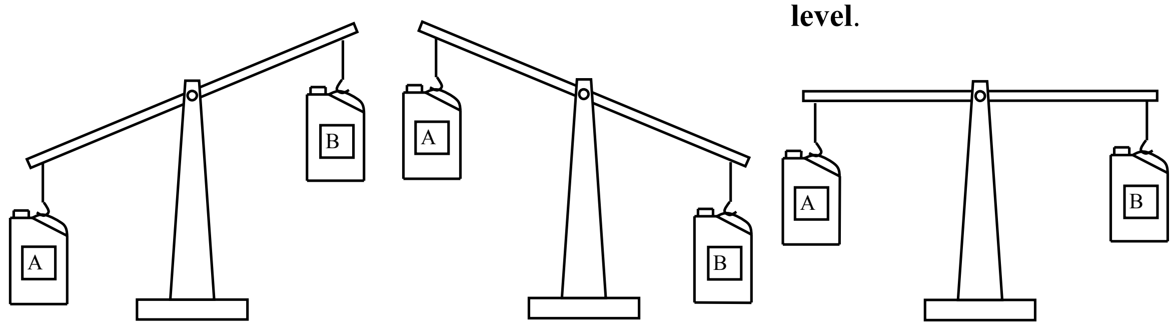
This means that **'A' and 'B' have the same mass**.

Next, they use a bicycle pump to pump some extra air into can B.

Daniel says: The extra air in B will make it **lighter**, so it will go **upwards**.

Inderjit says: The extra air in B will make it **heavier**, so it will go **downwards**.

Michael says: The extra air will make **no difference** to the mass of the cans, so the balance beam will **stay level**.



Which of the boys do you think is right?

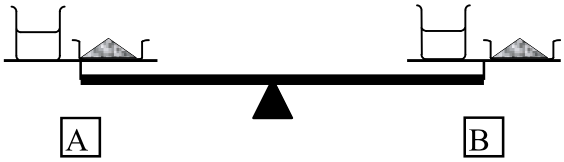
Use the particle model to explain what happens to the mass of the can when air is pumped in. Use words and pictures.

Name:

Modelling change student sheet 4B

Test question 2: Dissolving

Sonia, Lisa and Hadia are weighing sugar and water.

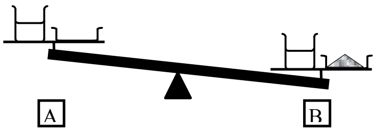


The balance beam is level.

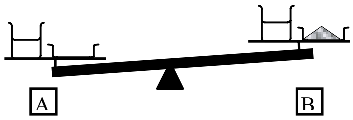
This means that **'A' and 'B' have the same mass**.

Next, they mix the sugar and water on side A. The sugar can no longer be seen.

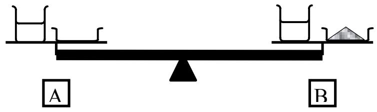
Sonia says: Side A will be **lighter**.



Lisa says: Side A will be **heavier**.



Hadia says: Sides A and B will have the **same** mass.



Which of the girls do you think is right?

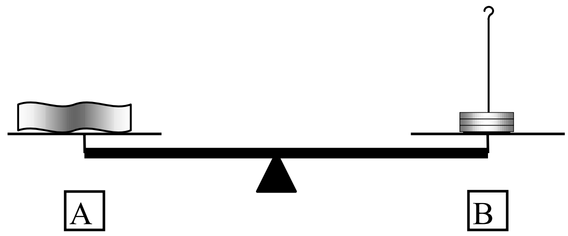
Explain your answer. Explain what happens when you dissolve sugar in water in terms of particles.

Name:

Modelling change student sheet 4C

Test question 3: Magnesium ribbon

Fiona, Alison and Louise are doing some burning and weighing work. A small amount of magnesium ribbon was placed on side 'A', and weights were added to side 'B' to balance the scales.

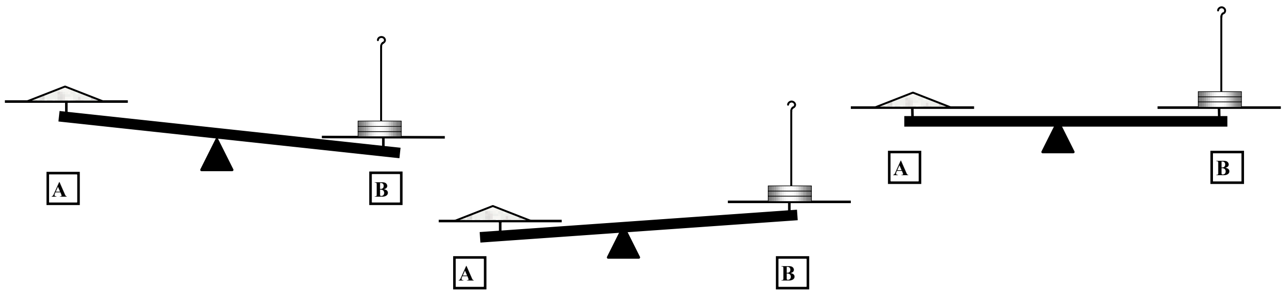


The magnesium ribbon was then removed and heated in air. It formed a white powder, which was carefully collected and returned to side 'A'.

Fiona says: Side A will be **lighter**.

Alison says: Side A will be **heavier**.

Louise says: Sides A and B will have the **same** mass.



Which of the girls do you think is right?

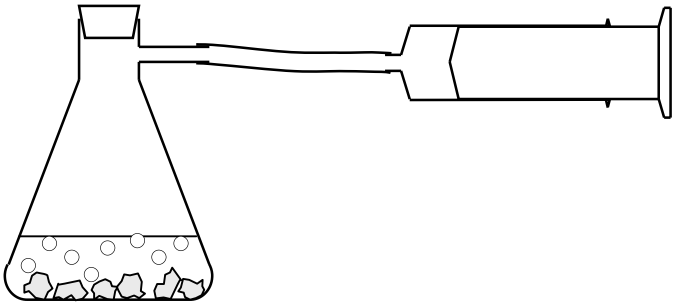
Explain your answer. Explain what happens when you burn iron wool in air in terms of particles.

Name:

Modelling change student sheet 4D

Test question 4: Dissolving rock

Fergus, Mark and Tim are doing an experiment in their science class. They have put some white limestone into dilute acid. They see bubbles of gas being given off as the limestone dissolves. They are collecting the gas in a syringe.



They have put their apparatus on a balance.

Fergus says as the gas is given off the apparatus will **get lighter**.

Mark says as the gas is given off the apparatus will **get heavier**.

Tim says as the gas is given off the mass of the apparatus **stay the same**.

Which of the boys do you think is right?

Explain your answer by showing what happens to the particles.

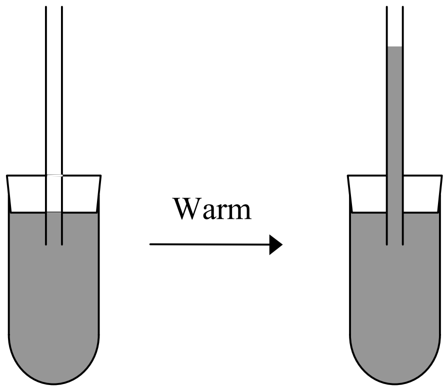
Name:

Modelling change student sheet 4D

Test question 5: Blue liquid

This tube is filled with a blue liquid called *Methylated spirits*.

If you hold the tube in your hands, the liquid warms up, and the blue colour moves up the thin capillary tube.



What happens to the **mass** *of the apparatus as it is warmed?*

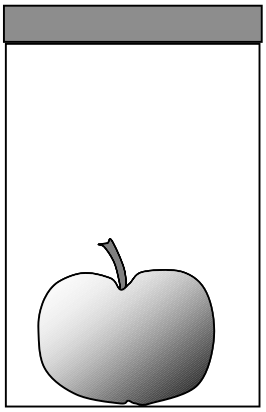
Explain what is happening in terms of the behaviour of the particles:

Name:

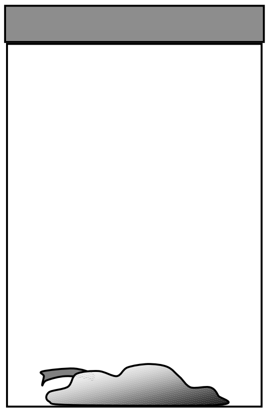
Modelling change student sheet 4F

Test question 6: Rotting apple

January



April



In January, Sophie finds an apple in the fruit bowl that has started to rot.

She puts it in a jar, and seals the jar firmly. **The jar is completely airtight.**
She weighs the jar. It weighs 275g.

The apple rots more and more. By April it is much smaller, and looks soft, brown and wet.

What do you think will have happened to the mass of the jar and contents by April?

By April, I think that the mass of the jar and contents will have ***decreased a lot*** *to about 250g*	
By April, I think that the mass of the jar and contents will have ***decreased, but only a little bit*** *to about 272 g.*	
By April, I think that the mass of the jar and contents will be ***exactly the same****.*	

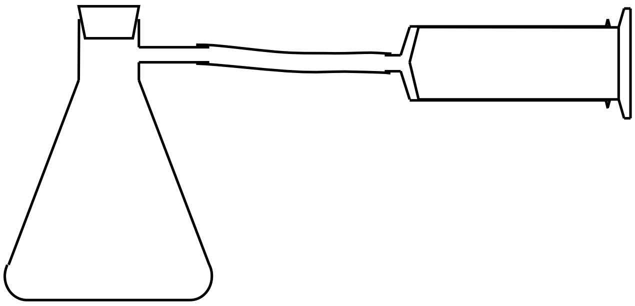
Explain your answer as carefully as you can:

Name:

Modelling change student sheet 4G

Test question 7: Air in a flask

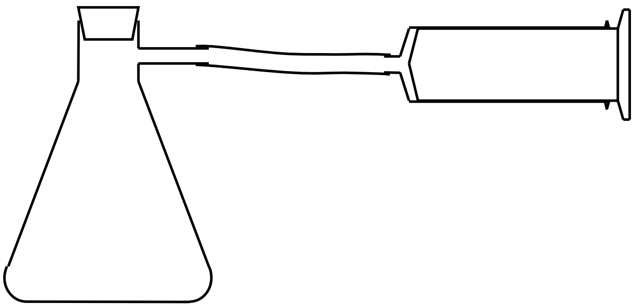
Xavier is learning about air in science. His teacher has set up the following apparatus:

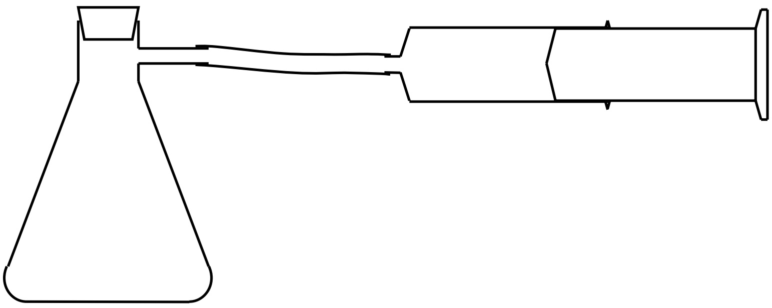


The teacher uses the syringe to remove some air from the flask:

Draw the air particles before and after the teacher removes some air from the flask:

Before: *After:*





Explanation: