HEATING AND COOLING MATERIALS

Science background for teachers

VOCABULARY

Solid, liquid, gas, change of state, physical change, chemical change, heating, cooling, melting, freezing, boiling, evaporation, hot, cold, condensation, steam, water vapour, reversible, permanent, irreversible, Celsius, thermometer

Heating and cooling materials can be associated with a change of state between solid, liquid and gas if the temperature changes are large enough. If the change is just **physical** then it can be reversed, as in melting chocolate or freezing water, but sometimes heating brings about a **chemical** change and is permanent as with heating (firing) clay or cooking eggs. Albumen (egg white) is mostly water but about 9 per cent protein and when heated the protein structure is changed permanently. For younger children a chemical change is very difficult to understand and best left to description only, 'what happens when we…?' For older children questions can be asked about the reversibility or not of the process and permanence of the change, and whether or not they think a new material has been formed. This increases their awareness of the different types of change being possible and helps to develop the idea of a chemical change.

In the solid state, the particles that make up a material are vibrating about a fixed point, packed closely together. As heat is applied, energy is gained and the particles vibrate more, reducing the forces holding them together. They move apart, breaking the solid structure and become a liquid. This is called **melting.** When further heat is applied, the particles move even faster, breaking away from each other and forming a gas or vapour **(evaporation).** When this happens to all the particles it is called boiling.

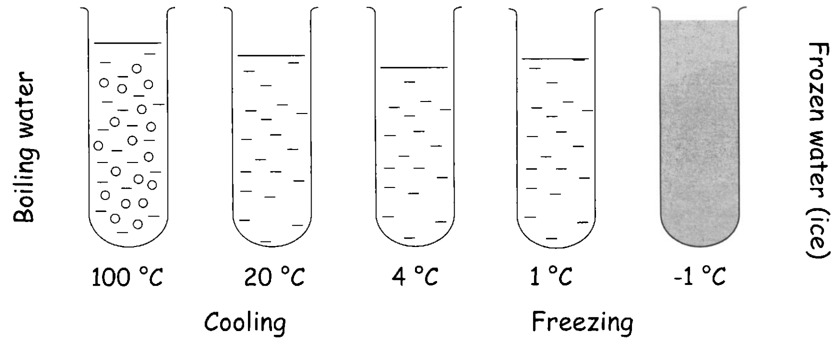
On cooling, the particles in the vapour slow down, come together and loosely bond, returning to the liquid state **(condensation).** Further cooling slows the movement of the particles even more and they become solid. If this happens at or near room temperature, as with chocolate or wax they are said to **solidify.** If this takes place at cold temperatures as with water it is known as **freezing**.

Children need to be aware of these changes in a variety of materials including water, which has an unusual property.

WATER

Most substances decrease in volume when cooled and increase in volume when heated. Water is no exception to this, except at temperatures between 0-4 °C, because when water melts, it contracts. At 0 °C, water is ice, which has an open honeycomb structure. This takes up more space than water in the liquid state and so there is an increase in volume. This is why pipes burst and the tops pop off frozen milk bottles. As the ice begins to melt between 0-4 °C, the honeycomb structure collapses and the volume decreases, so at 4 °C its volume is at a minimum and it is most dense. This also explains why ice floats on water and in ponds there is life under the ice. The ice at 0 °C is less dense than the water between 0-4 °C, therefore the ice floats and the water stays at the bottom of the pond. Above 4 °C, the water expands as it warms up.

A diagram (exaggerated) to show changes in volume of water at different temperatures



If chemicals such as salt are added to ice, the freezing point is then lowered to about -10 °C. Salt on the surface of ice dissolves forming a salt solution with a lower freezing point than the ice on which it sits. This causes the ice to melt, more salt dissolves and so on. This process also causes the temperature to drop and is called an endothermic reaction.

When water is heated to 100 °C it boils and the liquid turns to a gas, which are the bubbles seen in boiling water. The gas escapes as invisible steam, the name given to the gaseous state of water at 100 °C or above. The visible cloud we often call 'steam' is actually tiny, condensed, water droplets that are light enough to remain suspended in the air as a mist or a cloud. Water can also exist as a gas in the air at a temperature below 100 °C, this is known as water vapour. When steam or water vapour get a lot cooler they condense back to the liquid state.

EVAPORATION

When liquids are left out and exposed to the air, they eventually 'dry up' or evaporate. This is due to the particles on the surface of the liquid being able to escape, turning to the gaseous state and moving away from the rest of the liquid. As the particles close to the surface move away, the liquid decreases until none is left. The process of a liquid changing to a gas below its boiling point is called evaporation.

TEMPERATURE

Temperature is a measure of how hot or cold something is and can be measured in a variety of ways. The most common piece of apparatus for measuring temperature in primary schools is the spirit thermometer with temperature measured on the Celsius scale. A thermometer is a thick glass tube with a very thin bore filled with liquid, which ends in a thin-walled reservoir. The liquid in the reservoir is very sensitive to temperature change and as the temperature increases, the liquid expands and rises up the narrow bore. 'Feeling' the temperature of something is not a very reliable measure due to the different thermal conducting properties of different materials. (See section on Thermal insulation.)

SKILLS

- Using a thermometer with care, reading the scale.
- Using a stopwatch accurately.
- Measuring volume and mass with care.
- Careful observation.
- Tabulating results and constructing graphs.
- Planning for a fair test, using equipment with care.
- Working cooperatively in a group.
- Following instructions.

Key ideas and activities

These begin with activities for younger children (4-7 year old students) and progress to older children (8-11 year old students).

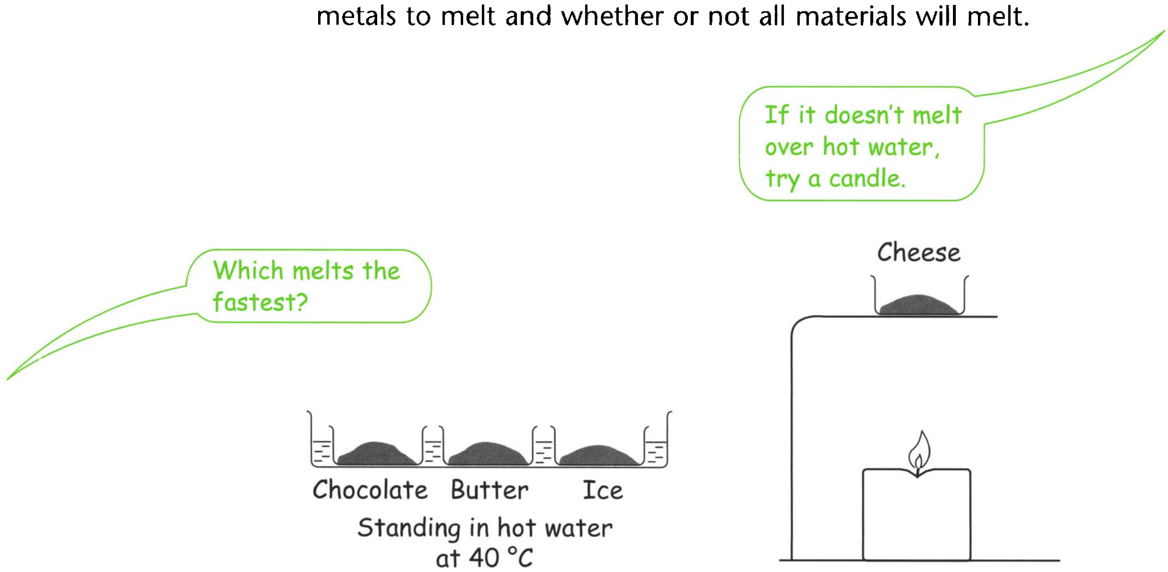
Some materials change when they are heated, some changes are reversible and some are not

Word processing

(a) Put small quantities of different substances eg chocolate, wax, butter, margarine, ice cube, cheese, pasta, plasticene into small, plastic 'mousse' pots or tin-foil pastry cases, and stand them or float them on hot water. The children can observe the substance melting. Do they all melt, if not, why not? Now put them in cold water and watch them solidify.

(b) Children could **investigate** 'which melts the fastest?' To keep the test fair, compare the same quantities, eg equal cubes of margarine, butter and chocolate.

(c) **Different materials melt at different temperatures** Older, more able children can **investigate** the fact that materials melt at different temperatures. This may be apparent to them from the outcome of activity (a). At primary level with simple equipment, this activity is limited to a few materials the children can melt. However, in a practical way it introduces the concept of materials melting at different temperatures. It may also lead to a discussion about the temperatures needed for other materials such as metals to melt and whether or not all materials will melt.

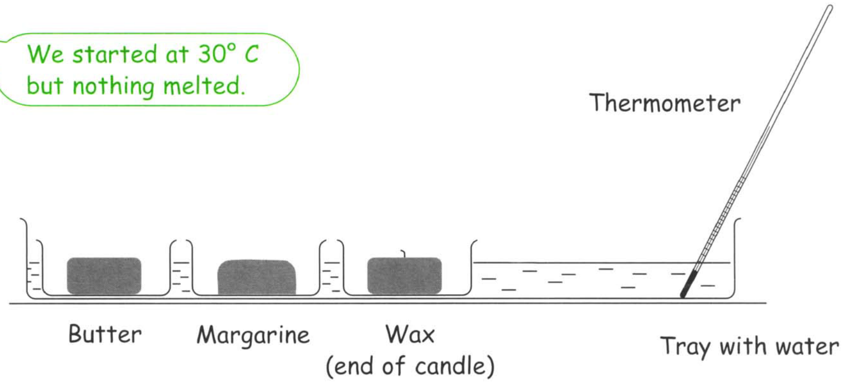


Safety!

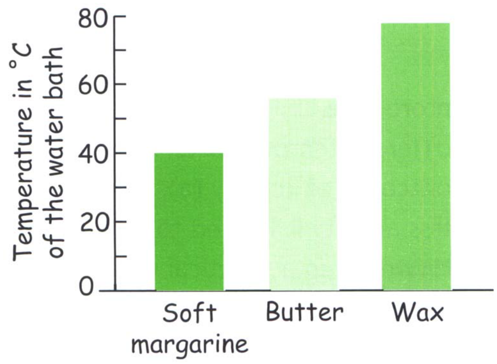
- Discuss the hazards and risks associated with this activity. The children doing this activity, should be well supervised.

Limit the children to a few materials that will melt at the temperature of very hot water (80 °C) or below, such as soft and hard fats, chocolate and wax. Use small, equal cubes of each substance and place each one into a dish. Place these into a large container of water with a thermometer. Begin the activity with warm water (30 °C) and see if any substance begins to melt. Remove the dishes, add hot water to the water bath, stir and take the water temperature. Replace the dishes to see which substance melts at the higher temperature. Record the water temperatures as different materials melt. A bar graph can be made of the results.

We started at 30° C but nothing melted.

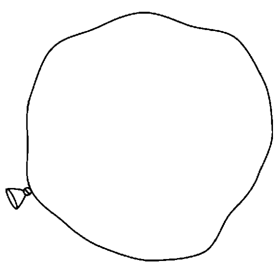


Graphing package



A graph to show the temperature at which materials begin to melt

How long will it take to melt?

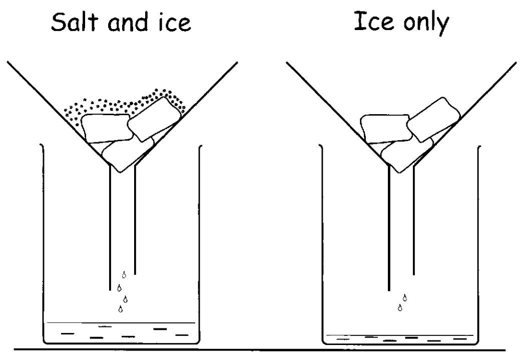


Ice Balloon

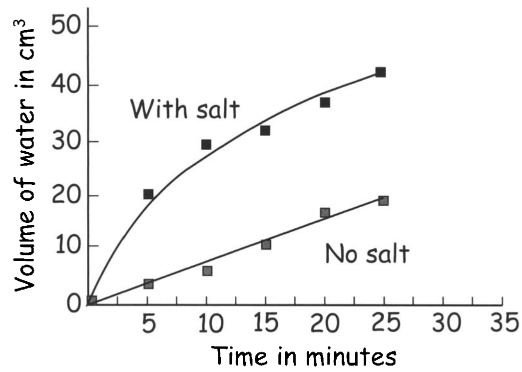
I can hear the ice cracking.

(d) **More melting ice** Great fun for younger children. Fill different containers with water eg balloons, rubber gloves, ice trays, yoghurt pots etc, freeze them and present them to the children to watch them melt during the day. You can peel the balloon away from the ice to leave the smooth, ice ball. Ask them how the process might be speeded up or slowed down (thermal insulation), and which they think will melt first. Float the balloons on warm water. You could use the concept cartoon ***Snowman*** here (see page 32).

(e) Older children might **investigate** 'Does salt affect melting ice?' Discuss the use of salt and grit on icy roads then carry out an **investigation** which they may plan themselves, or direct the activity. Prepare two beakers and funnels, put the same quantity of ice in each funnel. Pour salt on one lot of ice and time the melting as the water drips into the beakers. (For more able pupils a thermometer can be put into the ice cubes to note the temperature change). As an **investigative activity,** have two dishes each with the same quantity of ice cubes on. Pour salt on the ice the top of one dish and compare the melting of the cubes with the dish without the salt. Repeat the activity or do it at the same time and have a dish with the salt underneath the ice cubes rather than on top of them. Get the children to observe closely where on the cubes the melting begins.



A graph to show time taken for ice to melt



(f) **Cooking** A perfect opportunity to observe, describe and with older children explain and **investigate** the changes that take place during cooking activities (see recipe sheets, page 86).

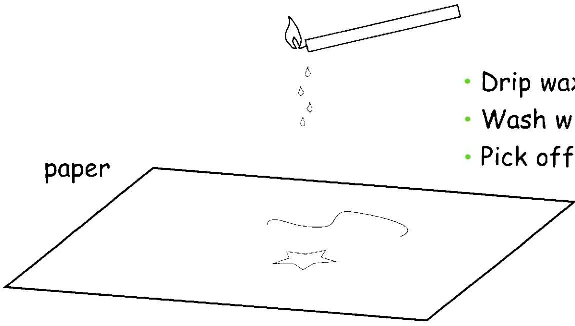
- Pastry cooking, eg jam tarts.
- Bread baking, **investigate** the effect of warm or cold water on mixing the yeast.
- Eggs cooked for different lengths of time or in different ways.
- Drop egg white using a dropper into different temperatures of water to see at what temperature it changes. Drop it into cold water first then into very hot water, try to find the critical temperature. An **investigation** for older children, 'At what temperature does egg white change?' (Because boiling point changes with pressure, it is not possible to cook an egg on the top of Mount Everest because the white will not change.)
- Cake making, make little cakes and **investigate** 'what happens if you leave them in the oven for different lengths of time?'
- Discuss the reversibility of these changes with older children. Are any new materials made?

(g) **Clay** As part of an art activity, children can explore clay as a material and model with it. As well as firing the clay, some can be left to dry out so that a comparison can be made.

(h) **Wax** Wax can be used for a variety of art activities. Old wax, candles or crayon stubs can be melted in a container over hot water. (Grating it first speeds up the process.) This can then be poured into new moulds and while it is solid but still soft and pliable it can be re-worked. Using an old paintbrush, the molten wax can be painted onto paper (or drip wax from a candle) then colour washed with inks or paint. The hard, dry wax can be picked or ironed off.
Wax may be painted onto fabric then dyed and when all is dry the wax is ironed out as in the 'batik 'technique, page 19.

Safety!

- Spirit thermometers should be used.
- Care with handling glassware.
- Care when handling hot and cold things.
- Candles should be stood in sand or water filled metal trays.



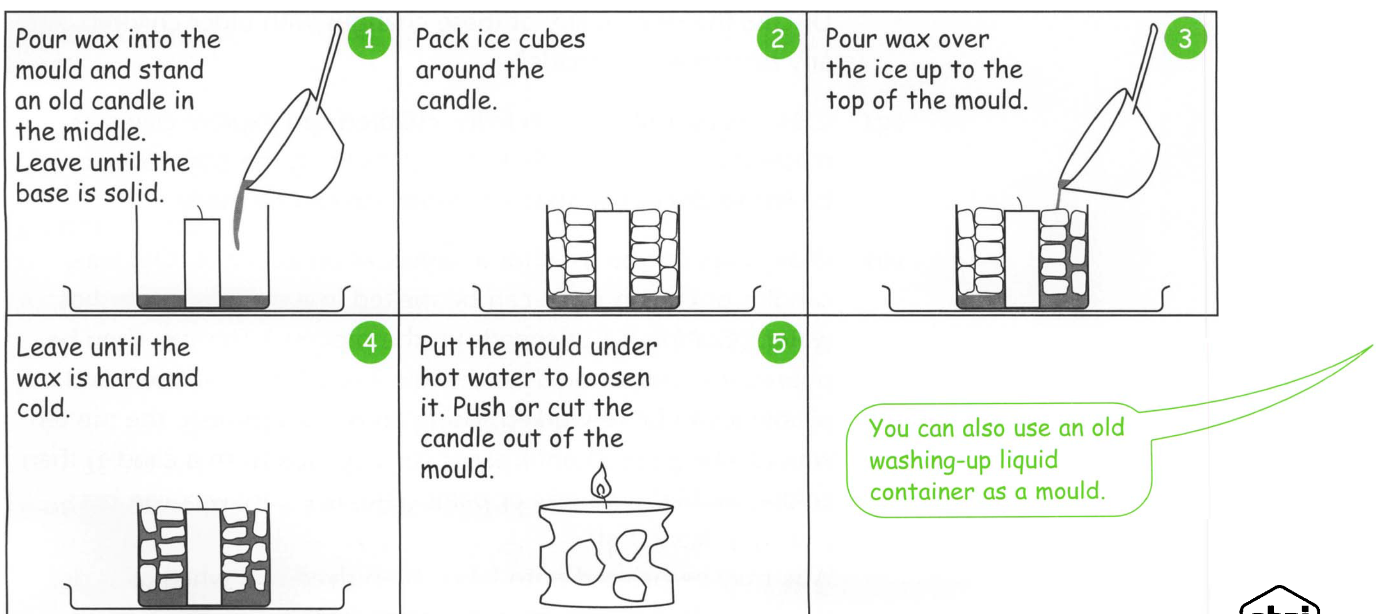
- Drip wax over paper, leave to dry.
- Wash with brush and ink or paint.
- Pick off dry wax.

Wax drip pictures

i **Wax candles** Different sized and coloured candles can be made using the stubs of old candles or specially bought wax. Wicks and wax colour tablets can also be bought from craft shops (see resource list). Used washing-up liquid containers, cut down, make good candle moulds.

ii **Dipping candles** Make up a molten coloured wax mix using plain wax and a colour tablet. Using a plain, white household candle and masking tape, create a pattern on the candle, then dip the candle into the coloured wax.

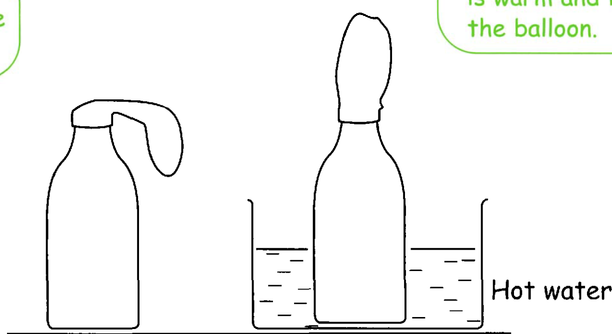
iii **Ice candles!** As a demonstration or with well supervised children, but great fun! For a mould use a cut down washing–up liquid container and have ready an old candle cut to the same height. Melt some wax (old candles are fine) and pour a little into the bottom of the mould to make a base. Stand the candle in this and hold until firm. Pack the space between the candle and mould with broken but not crushed ice cubes. Now pour the rest of the molten wax over the ice to fill the mould. Leave it to stand for half an hour. When it is cool and firm, run under a warm tap to loosen the wax and push firmly out of the mould. You have a candle like a Gruyere cheese! It is worth making one to show the children first and asking them how they think it is made. A lot of discussion about changes of state of different materials is possible here.



(i) Expanding gases You need a bowl of hot water, a bottle and a balloon that will fit over the neck of the bottle. Discuss with the children what is in the bottle, put the balloon over the neck and stand it in the hot water, the balloon inflates. Then take the bottle out and watch the balloon deflate. **Investigate...** 'Does the size of the bottle affect the amount the balloon inflates?' Or 'Does the temperature of the water affect the amount the balloon inflates?'

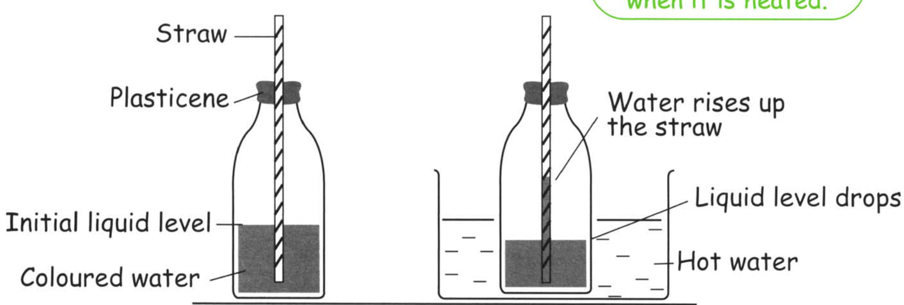
What happens if we change the temperature of the water?

Air expands when it is warm and inflates the balloon.



(j) Expanding Liquids Fill a small bottle up to the top with coloured water, insert a clear straw and secure in place with plasticene to make a seal. Stand the bottle in hot water and watch the liquid rise up in the straw. If you use a plastic bottle the water goes down first then rises, due to the initial expansion of the plastic. (Glass does not expand very much.)

Water expands when it is heated.



(k) Making a thermometer Ideally the children would do this activity after using a commercial thermometer and doing the above activity on expansion of liquids. Half fill a small bottle with cold, coloured water. Mark a clear, plastic straw with 1 cm intervals and place it in the neck so that it touches the liquid and secure in place with plasticene. Push down on the plasticene so that water begins to fill the straw. As the water in the bottle warms up the water rises up the straw like a thermometer. This can be dramatically shown, by standing the bottle in hot water. Remember, with plastic bottles there is initially a drop in the water line because the plastic expands.

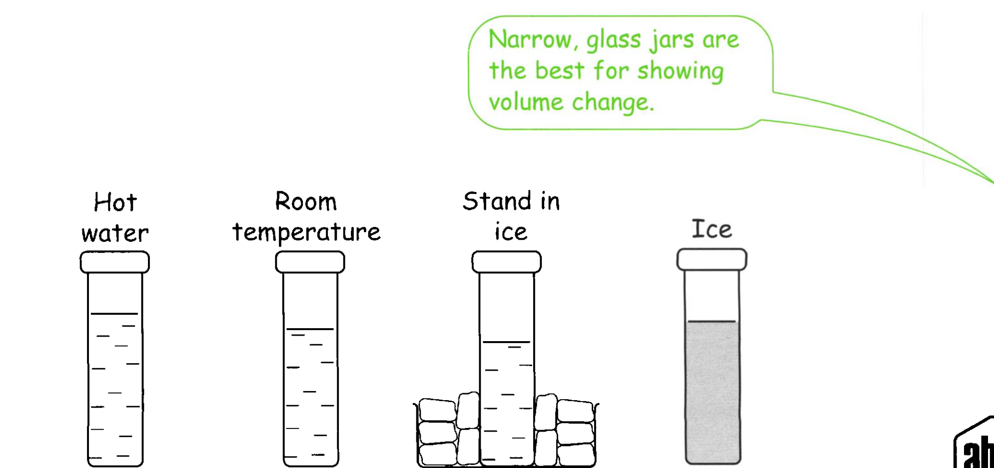
(l) **Liquids evaporate when we heat them** Heat water in a heatproof container gently over a candle and watch it evaporate as the liquid turns to a gaseous state. If you have Pyrex® beakers the liquid level can be marked at timed intervals. Repeat and compare with other liquids such as lemon juice. (Vinegar gives off a very strong smell when heated.)

(m) **Water boils at 100 °C to produce an invisible gas called steam** A demonstration for older children is to watch water boiling in a saucepan on a cooker or in a kettle. The teacher should take the temperature of the water as it boils. (Use a thermometer that measures to 110 °C.) Discuss the bubbles and the 'steam' they see. If you also use a kettle, there is a gap (observed against a dark background), due to the invisible steam, immediately above the kettle spout. Take the temperature here then higher above in the water vapour cloud. As a safety issue discuss the hazards and risks with the children.

Some materials change on cooling

(a) **Change of state-liquid to solid** This activity is the converse of activity (b) 'More melting ice' in the previous section and could precede it. Get the children to fill different shapes with water and put them in the freezer overnight. They should also explore freezing other liquids such as milk, oil, juice and vinegar.

(b) **Water is an unusual substance, it expands when frozen** Older children could **investigate** the change in volume of different liquids including water as they cool down from very hot to frozen. As most liquids that they are likely to come into contact with contain a large proportion of water, they will find that many will expand on freezing. This is a good discussion point. This is also a good opportunity to construct a line graph of temperature and volume. Using a glass container initially will also minimise the effect of the hot liquid on the material of the container. Half fill a small, glass bottle or jar with hot water, cover it to prevent loss through evaporation and mark the liquid line. As it cools, note the temperature and any change in the liquid line. To go below room temperature, the container can be put in the refrigerator or stood in ice. Finally, put it in a freezer.

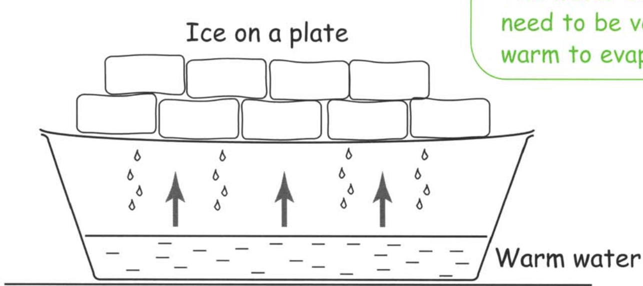


(c) **Ice damage** This activity could lead to a good discussion about the damage done when water seeps into rocks and bricks, then freezes and expands causing them to crack. This also happens to burst pipes. Fill a plastic bottle to the top with water, put the top on and freeze it. Some plastic bottles are more flexible than others and will 'give' more, try to use a rigid one and it will split. Try putting a small screw top glass jar full of water in a clear, plastic bag and freezing it.

(d) **Steam and water vapour cool to produce water, this is called condensation** This demonstration may be done at the same time as the above activity on 'Water boils at 100 °C to produce steam' in the previous section. Put a large mirror or cold shiny saucepan above the boiling water and watch the steam turn to water and the condensation appear on the shiny surface. This can also be done with water that the children gently heat over a candle themselves. It does not have to be boiling water to evaporate and condense on a mirror. It works best if the mirrors are refrigerated for a while first. Traditionally, we get children to breathe on a cold mirror, the problem with this is the initial understanding that our breath contains water. This therefore may be done after the previous activity with the question 'what does our breath contain?'

(e) Put crushed ice in a glass jar and cover the top to show that water is not escaping! Leave the jar for about 10 minutes (depending on the outside temperature). As the warm water vapour in the air touches the cold glass, it condenses leaving the outside of the glass wet. Note that some children are still convinced that water from the ice is the cause of this! Also try cold cola cans from the refrigerator, an everyday experience for many children.

(f) Put a plate of ice over a transparent bowl of warm water and watch the warm water vapour hit the cold plate, condense and drip back into the bowl.



The water does not need to be very warm to evaporate.

star* Poetry

by Michael Rosen

Chippy Breath Writing in the condensation on bus windows.

Hot Cat Different things melt at different temperatures!

Some Thoughts About Eggs Eggs can be cooked in a variety of ways.

Grandad's Airer Clothes drying on an airer.

Hot Pants Hot air dries clothes in a tumble drier.

Steamy Shower Evaporation and condensation in the bathroom.

Thirsty Land The sun dries up the water on the land.

Scoop a Gloop Materials change when they are heated, clay is a permanent change. See page 9.

Chippy Breath

After football
my dad buys me fish and chips
and my hot chippy breath
makes clouds in the air
and rain on the windows
of the bus
all the way home.

I write the score
on the wet glass
– but only when we win.

Hot Cat

The butter melted
the cheese went mouldy
it all got so hot
the cat moulted.

Then it got hotter
the cheese melted
and the cat went mouldy.

Then it got hotter
and the cat melted.

Some Thoughts about Eggs

1. Is a hard-boiled egg one that was hard to boil?
2. How fast do runny eggs run?
3. It can't be very fast because my dad beat one.
4. If the white bit's called the 'white', why isn't the yellow bit called the 'yellow'?
5. If a piglet is a little pig, is an omelette a little om?
6. What is an om?
7. You put mushrooms in mushroom omelettes, you put cheese in cheese omelettes. I'm worried about what they put in Spanish omelettes.
8. Why don't eggs melt when you heat them up?
9. Who lays Easter eggs?
10. If we had an egg we could have egg on toast – if we had some toast

star* Poetry

Grandad's Airer

My Grandad says
when he was a boy
he lived in a flat
and in winter
when they wanted to dry the washing
they used an 'airer'.

It was like a clothes horse
lying on its side
that they hoisted up to the ceiling
with a rope and pulley.

The trouble was, he said,
it was next to the cooker.

Just where
they fried liver and onions.

So when he stood in line at school
the kids behind would sniff his shirt
and point and say:
'Liver and onions!'

Steamy Shower

I love a
dreamy, steamy shower
hanging about
for over an hour
just before bed
getting hot and red
in the steam
standing there
with time to dream
water-running-over-me feeling
drips dripping off the ceiling
mum says it's my fault it's peeling
nothing can beat
the hot wet heat
nothing wetter
nothing better
I love a
dreamy steamy streamy shower

Hot Pants

The tumble drier
dries socks hot
and hot socks
make my toes warm.

All through winter
when it's wet and cold
our tumble drier
rumbles round.

Hot socks
hot shirts
hot skirts
hot pants

All through winter
in the wet and cold
I watch where the pipe
from the drier ends:

It's where there's a grille,
and through the holes
the drier breathes out
hot air.

Hot air
hot breaths
hot puffs
hot pants.

Thirsty Land

In the plane over the desert
I see the badlands beneath us
wrinkled like old skin.

Ancient river valleys
are now dry brown snakes.

The sun that glares at this
has dried up
every last drop.

Even the rocks begin to say:
'Water, please, water.'

COOKING RECIPES

Biscuits

125 g butter/margarine
150 g caster sugar
1 egg yolk
225 g plain flour
grated lemon
mixed spices or vanilla

Cream the fat and sugar until white, then add the egg yolk and beat. Stir in the flour and flavouring. Knead lightly, roll out and cut with a cutter. Put on a greased baking sheet and bake for 15 min at 180 °C (350 °F, gas mark 4). Take a few biscuits out at 5 minute intervals to see the effect of time or bake at different temperatures.

Bread

700 g strong plain flour
2 teaspoons of salt
1 teaspoon of fat or oil
1 teaspoon dried yeast
1 teaspoon caster sugar
400 ml tepid water

Mix about 100 ml water with the sugar, add the yeast and whisk. Leave until frothy. Mix the flour, salt and fat then add the yeast mix. Knead until smooth then leave in a covered bowl to rise in a warm place. Knead the dough again and put into a greased loaf tin or divide into small pieces for rolls.

Investigate water temperatures for the yeast and make a batch of bread without it.

Cakes

100 g butter or margarine
100 g caster sugar
2 beaten eggs
100 g self-raising flour

Cream the fat and sugar until white add the eggs and beat. Fold in the sieved flour. Put into small tins or cases and bake for 15-20 min. Investigate different cooking times on some of the cakes or investigate using baking powder as a raising agent instead of S.R. flour. (225 g plain flour : different amounts of baking powder.)