Smart Colours

Devi Stuart-Fox, an Australian scientist has, as a result of her studies of the colour in lizards and birds, shown that the remarkable ability of chameleons to change colour evolved not as camouflage, but as a social and territorial display. She has also found out that bearded dragons change colour in response to heat – they are thermochromic. Many of your children will have seen thermochromic mugs, ask them to think about how materials which change colour due to a difference in heat could be used in the home.

As a result of Devi's studies other scientists are now developing bandages, smart bandages, that change colour in response to slight changes in the temperature of the wound.

Scientists have invented colour-changing bowls and spoons which let parents know if the food for babies is too hot plus toys which change colour in the bath indicating the waters' temperature.

Children may also have seen the colour changing thermometers which are placed on the forehead.

Everyone's heard the phrase "red hot," but what does it actually mean? If you heat an iron bar in a furnace, you'll see it slowly changes colour from its original gray-black (at about 600°C) to red hot (~950°C), yellow hot (~1100°C), and then white hot (at higher temperatures still). The hotter it gets; the more energy it contains. As the fire pumps energy into the iron, the irons' atoms become "excited" and unstable, and their electrons absorb the energy briefly, then hurl it back out again in the form of light particles known as photons. That's generally why hot things change colour—and why their colour changes (from red to white) as they get hotter and spew out different kinds of light energy. It's an example of what's called incandescence, where heat energy is constantly converted to light energy.

Thermochromic materials change colour at much lower temperatures and for very different reasons that have nothing to do with incandescence. There are two main types of materials that are widely used to produce thermochromic effects. Some use **liquid crystals** (the materials from which your computer or mobile phone display is most likely made); others use organic (carbon-based) dyes known as **leuco dyes** the dyes used in the FriXion pens.

Sometimes we want things to change colour as they get hotter or colder just for novelty or entertainment.

Or maybe you have a T-shirt or a poster that changes colour when you touch it?

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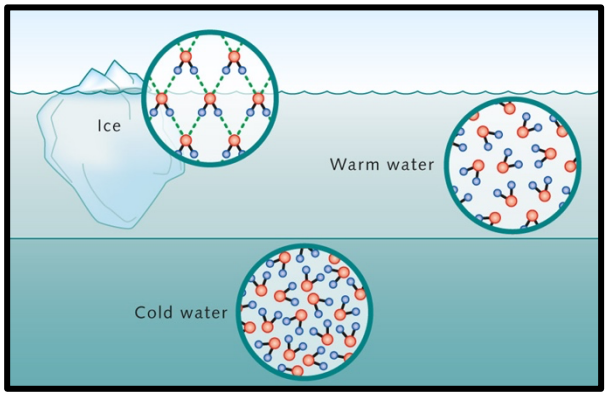
Puff the Magic Dragon Setting the Scene

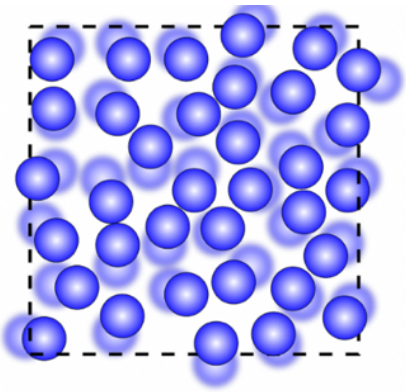
- Place a thin sheet of paper over the dragon.
- Using one of the darker FriXion pens trace the outline of the dragon.
- Using the other FriXion pens colour in your dragon.

This explains why solids have a fixed shape and volume.

On freezing, water molecules rearrange themselves into hollow rings. This is why water expands (thus becomes less dense) when it freezes unlike other liquids which contract – hence solid water (ice) floats!



Liquids have a much looser shape than solids; they can be poured easily and cannot be physically held without a container. Liquids move to fill the shape of the container they are in. If they are not held by a container, they will move as far as gravity will take them.

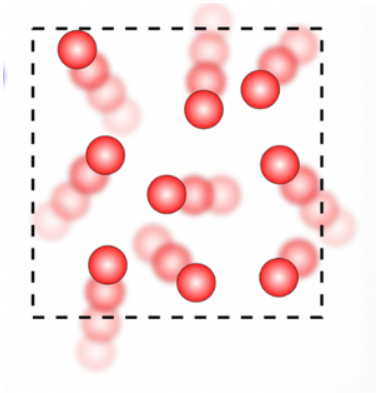


The particles in a liquid:

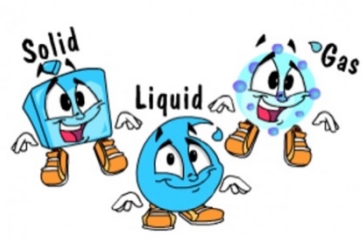
- sit close together but some gaps have appeared;
- can move past each other because of the gaps;
- have enough energy to prevent the forces between them holding them in a fixed, regular arrangement;
- are randomly arranged.

This explains why liquids have a fixed volume but take on the shape of their container.

Gases have the loosest shape of all the three states of matter, so they are the hardest to contain. Similarly, to liquids, gases spread themselves out to fill whatever space they are in. Whilst gases are affected by gravity, they are not affected in the same ways as liquids or solids. Gases are often invisible.
The particles in a gas:



- are much further apart;
- are entirely free to move because the forces between them are weak;
- are randomly arranged;
- move quickly and randomly in all directions.



- ***solids have a fixed shape and volume;***
- ***liquids have a fixed volume but take on the shape of their container;***
- ***gases completely fill their container and have the volume of their container.***

to be removed from the solution before freezing can occur i.e., the solution freezes at a temperature lower than 0 ^{o}C; **Salt acts as a freezing point depressant.**

The movement energy of the molecules in a substance is related to the temperature. If the molecules initially have a lot of kinetic (movement) energy and we then remove heat from the substance, the molecules will then also lose kinetic energy; the less kinetic energy they have the lower is the temperature.

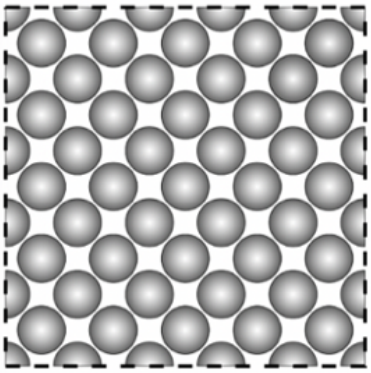
By adding salt to water more heat energy must be removed before the solution can freeze and, furthermore, the more particles of salt added, the more kinetic energy must be removed from the solution before it freezes, in other words: the greater the concentration of the salt (solute) the lower will be the freezing point of the water (solvent).

For a solution of table salt in water, under controlled laboratory conditions, the freezing point of water has been measured at -21 ^{o}C. In the 'real' world say on pathways, roads and steps leading up to front doors; sodium chloride can melt ice down to -15 ^{o}C. **This is why gloves must be worn by your volunteer.**

Ice has to absorb heat energy in order to melt, in this demonstration; the heat energy is absorbed from the water, the surrounding air and the hands holding the bag. When you add the salt to the ice, it lowers the freezing point of the water-salt solution. To melt the newly formed ice which is at a temperature now less than 0 ^{o}C, even more energy has to be absorbed from the environment in order to make it melt. The newly formed ice is now colder than before.

States of Matter

Solids have the firmest shape of the three states of matter; they do not flow like liquids or spread themselves out like gases. Solids can be physically held, and stay the same shape unless acted on by an outside force. Similarly, solids stay in one place unless moved by an outside force.



The particles in a solid:

- sit very closely together;
- are in a regular arrangement and in fixed position;
- vibrate about a fixed position but do not move through the solid;
- are held together by strong forces.

If you have an aerosol spray for cleaning your white board – try spray that onto the invisible dragon – what happens? what does that tell you about the temperature of the gas leaving canister?

Science in a Nutshell - Smart Pens – FriXion by Pilot

The secret behind the magic is in Pilot's proprietary thermochromic ink. The ink uses three types of chemical compounds that rely on:

- acid-base and temperature sensitivity:
- special types of dye that change colour upon reaction with acids;
- compounds that act as acids to produce the colour change; and
- compounds that regulate the temperature at which the colour transition will take place.

Thermochromic inks are heat sensitive and become semi-transparent and are mainly used to reveal a printed message hidden underneath the ink when a temperature change occurs. The most common heat reactive ink is used to reveal a message by heating it up, usually by rubbing. This is the ink in the FriXion pens.

The dyes are called leucodyes and they are chemicals that change colour when heat energy makes their molecules shift back and forth between two subtly different structures – known as the leuco (colourless) and the non-leuco (coloured) forms. The leuco and no-leuco forms absorb and reflect light different, so appear very different colours when printed on a material such as paper or cotton

To heat the ink Scientific Sue used a hair dryer – how else could you heat the image of Puff safely?

To cool the image of Puff down we need to achieve temperatures below 0 ^{o}C – hence the need to add salt to the ice.

Pure water freezes, or melts, at 0 ^{o}C and boils at 100 ^{o}C. Therefore, between 0 ^{o}C and 100 ^{o}C, water exists in the liquid state. Its molecules are provided with enough heat energy and hence kinetic (movement) energy to move around, but not enough energy to break the relatively loose, 'sticky', bonds between them. When you pour liquids into containers you will notice that they all flow and change shape to fit the dimensions of the base of any container you may pour them in to. The shape of a liquid can change, but its volume, at specific temperatures and pressure, always remains the same; you can test this by pouring a liquid into lots of different shaped measuring jugs: tall, thin, wide and short; the volume is always the same.

However, when the temperature is lowered to below 0 ^{o}C, the molecules cease to move around – they vibrate only - and they form the crystalline structure of ice, in which the molecules are held together by stronger, 'stickier', bonds.

When any substance freezes, the particles within it arrange themselves into an orderly pattern. This arrangement is called a crystal. When table or sea salt (sodium chloride NaCl) is added to water, a saline solution is formed and the forming of this solution interferes with the orderly arrangement of the particles in the crystal. The result of this is an increase in heat energy required

To speed up the disappearing process Scientific Sue gently waved a hair dryer (on the hot setting) behind the image of the dragon to make the dragon disappear.

The image can be recovered if the paper is cooled to temperatures below - 10 C. You can put the image in a clear re-sealable plastic bag and put it in the freezer.

Secrets for Success

Prepare your drawing of Puff the Magic Dragon before the show – see template below.
Half fill a large resealable bag with ice – remove any melted water before the show.

Making Puff disappear

Choose your volunteers 1 and 2.

Volunteer 1 will put on the gloves and will then hold the picture of Puff in front of them so that the whole class can see it – one hand above and one hand below. The hair dryer is warm – the gloves are to make sure hands are not heated.

Volunteer 2 switches the hair dryer on and uses it to blow heated air on to the back of the picture avoiding the gloves.

The image will disappear in a 'puff!' Switch off hairdryer

Volunteer 1 places the page, picture side up, on the tray – and removed the gloves.

Volunteer 2 puts on the gloves and lifts up tray holding it so that the picture is seen.

Volunteer 1 opens up the bag of ice (excess water removed) and pours the salt on top. they then close the bag securely removing as much of the air as they can in the process. Using their gloved hands mix the salt and ice together – then gently rub the ice bag over the image.

The dragon should then reappear.

If you have time take the temperature of the ice before the salt is added and then 10 s after it has been added.

Does the image reappear just using ice?

The Disappearing and Reappearing Dragon

What you have:

- Set of FriXion pens
- Template of Dragon

What you need:

- Hairdryer
- A 4 Sheet of Paper
- Small Resealable Bag
- Cup of Crushed Ice
- Cup of Salt
- Thermometer
- Paper Towels
- Tray (bigger than A4) or clipboard
- double sided tape or sellotape

SAFETY:

- Do not use the hair dryer near liquids.
- Do not let the hair dryer over-heat.
- Un plug the hairdryer when not in use.

The bag containing the ice and salt is not to be held by unprotected hands as the contents are cold enough to cause tissue damage! If you don't have any thermal Gloves or tea towels are needed to protect the hands from the cold.

Nuts & Bolts

When you rub the dragon drawn with the FriXion pens with the hard rubber eraser, heat from the resulting friction causes the temperature-sensing compound in the ink to activate acid compounds within the ink, thus allowing them to neutralising the alkaline dye. Heating the ink makes it virtually disappear!