The Litter Lab Show

Scientific Sue's Litter Lab

The Show content covers the following curriculum areas and more!

Properties of Materials:

- Investigate the properties of materials.
- Gain an understanding of the meaning of the words solid and liquid.
- Investigate the distinctive properties of solids and liquids.
- Show that solids have a definite shape and volume.
- Show that liquids have a definite volume but take on the shape of the part of the container that it fills.
- Recognise differences between solids and liquids, in terms of flow and maintenance of shape and volume.
- Gain ability to describe changes that occur when materials are mixed.
- Investigate how a wide range of materials may be changed by mixing.
- Examine the changes that take place in materials when physical forces are applied.
- Recognise that non-reversible changes, for example borax reacting with PVA glue, result in the formation of new materials that may be useful.
- Relate the properties of the material to its use.
- Gain an initial exposure to the concept of molecules.

Grouping and Classifying Materials:

- Be given the opportunity to compare everyday materials and objects on the basis of their material properties, including hardness, strength, and flexibility, and to relate these properties to everyday uses of the materials.

Forces and Energy:

- Investigate how forces can affect the movement and shape of objects.
- Investigate the effect of friction on the movement of objects.

Environmental Awareness:

- Explore examples, using the hagfish, to highlight the interrelationship of living and non-living aspects of local and other environments.
- Allow children to be taught about ways in which living things and the environment need protection.

Investigating and Experimenting:

- Be given the opportunity to design, plan and carry out simple experiments, having regard to one or two variables and their control and the need to sequence tasks and tests.
- To gain an appreciation that an experiment is unfair if relevant variables are not controlled.
- Identifying different ways of looking at a problem and comparing results of different investigations.
- Be given the opportunity to ask questions that can be investigated scientifically and help them decide how to find answers.

- Be given the opportunity to think about **(predict)** what might happen or try things out when deciding what to do, what kind of evidence to collect, and what equipment and materials to use.
- Be given the opportunity to make a fair test or comparison by changing one factor and observing or measuring the effect while keeping other factors the same.

Estimating and Measure:

- Use of appropriate simple instruments and techniques to collect and record data on length, mass, capacity and time.
- Use simple equipment and materials appropriately and take action to control risk.
- Check observations and measurements by repeating them where appropriate.
- Estimate and use standard units of measurement.

Recognising patterns:

- Look for and recognise patterns and relationships when making observations.
- Make comparisons and identify simple patterns or associations in their own observations and measurements or other data.

Health and Safety:

- Recognise that there are hazards in materials and physical processes, and assess risks and take action to reduce risk to themselves and others.

Breadth of Study:

- Gain ability to use appropriate scientific language and terms to communicate ideas and explain the behaviour of materials, phenomena and processes.
- Look at the part science plays and has played in the development of useful things.

Polymers

All atoms of a particular element have the same number of protons. Atoms of different elements have different numbers of protons.

The number of protons in an atom of an element is its atomic number. The sum of the protons and neutrons in an atom is its mass number.

At the very center of each atom is the nucleus. The nucleus is a cluster of particles called protons and neutrons. Protons have a plus (+) charge, and neutrons are neutral (that is, they don't have a charge).

The nucleus is very compact, and even though it accounts for most of an atom's weight, it takes up a very small amount of the atom's total volume. As a matter of fact, most of the atom is empty space! The rest of the atom has electrons crazily whizzing around it. Electrons have a minus (-) charge, and the number of electrons equal the number of the (+) protons, hence the overall charge of an atom is zero, they balance each other out. Electrons are so light, though, that they really don't count towards the total weight of the atom. However, electrons don't fly around just anywhere. They have set amounts of energy. The more energy an electron has, the further away from the nucleus it tends to be. The outermost electrons are called the valence electrons. Valence electrons have a special job - they can form bonds - or connect - with another atom.

Electrons occupy particular energy levels. Each electron in an atom is at a particular energy level (in a particular shell). The electrons in an atom occupy the lowest available

Atoms can have as many as 8 valence electrons. (Hydrogen and helium, can have 2, but no more.) A carbon atom has 4 valence electrons.

The kinds of atoms that exist are called elements. Some elements are: silver, gold, neon, and carbon. To see all of the elements in one place, look at a periodic table. All of the elements that exist are there on the periodic table, starting with hydrogen at number 1, on up to more than 100. That number, called the atomic number tells us how many protons each atom has. So, hydrogen has 1 proton, carbon has 6 protons, nickel has 28 protons and so on.

Every element has a symbol of one or two letters. Some of them make sense, like carbon is C and oxygen is O, and some of them don't, like the symbol for gold, Au. (Au is based on the Latin word for gold, aurum.)

Atoms, Elements and Molecules

Atoms are the basic building blocks of everything you can see around you, and even lots of things you can't see, like the air that we breathe.

Scientific Sue's Litter Lab

With Lego blocks you can build structures and with our atoms we build molecules.
When we look at Lego we see that the blocks can have a different number of connecting bumps, the joining ability of an atom depend on the number of positive protons it has in its nucleus – the atomic number. If we were to go to Lego World we could possibly see blocks which have hundreds of joining bumps on them; in our world however we only have just over 90 naturally occurring building blocks, atoms, and we can see them displayed in a periodic table these are our Elements.

When atoms join together, they form bonds and make molecules.

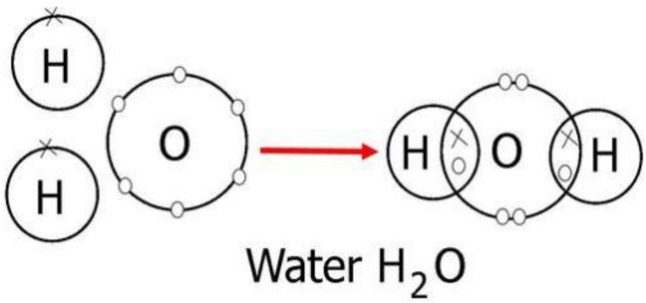
Molecules can be small like oxygen gas (O_2) and water (H_2O) or much bigger like citric acid $C_6H_8O_7$

So molecules are atoms joined together, but not just in any old fashion. Changing the arrangement structure of the atoms within a molecule can change the properties of a molecule i.e. how its looks and acts.

A Bonding Experience

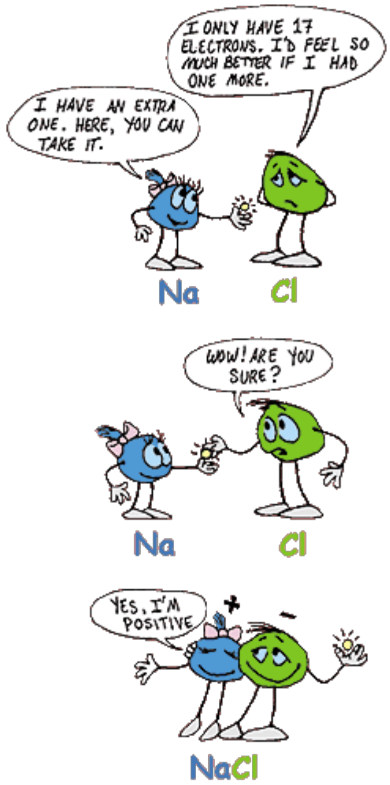
There are two basic kinds of bonds - covalent and ionic.

When elements react, their atoms join with other atoms to form compounds. This involves giving, taking or sharing electrons to form ions or molecules. Compounds formed from metals and non-metals consist of ions. Compounds formed just from non-metals consist of molecules. In molecules the atoms are held together by strong covalent bonds.



Covalent bonds happen when two atoms share electrons – in the science show Scientific Sue used the joining of Velcro strips to highlight the strength of covalent bonds - due to this sharing of electrons covalent bonds are strong. A lot of energy is required to break these bonds. When at least 2 atoms get together by sharing electrons, they form a molecule. **The force of attraction between each molecule is generally small.**

Scientific Sue's Litter Lab



Ionic bonds happen when one atom gives at least one electron to another atom.
Picture this: Two atoms sit next to each other. One atom needs an electron, and the other atom has an extra electron. Perfect! Once the electron gets handed over, the atoms are no longer atoms - they're ions, and they each have a charge - one plus (+ positive) and one minus (- negative).

Remember that each atom started with enough (-) electrons to match the total number of (+) protons in its nucleus. The atom that gets an extra electron ends up with a (-) charge and is called an anion. The atom that gives away an electron ends up with a (+) charge and is called a cation. These (+) and (-) charges create a strong force of attraction between each other. **An ionic bond is the strong attraction between ions with opposite charges.** Table salt is a good example of a common ionic compound. (Table salt is also called sodium chloride.)

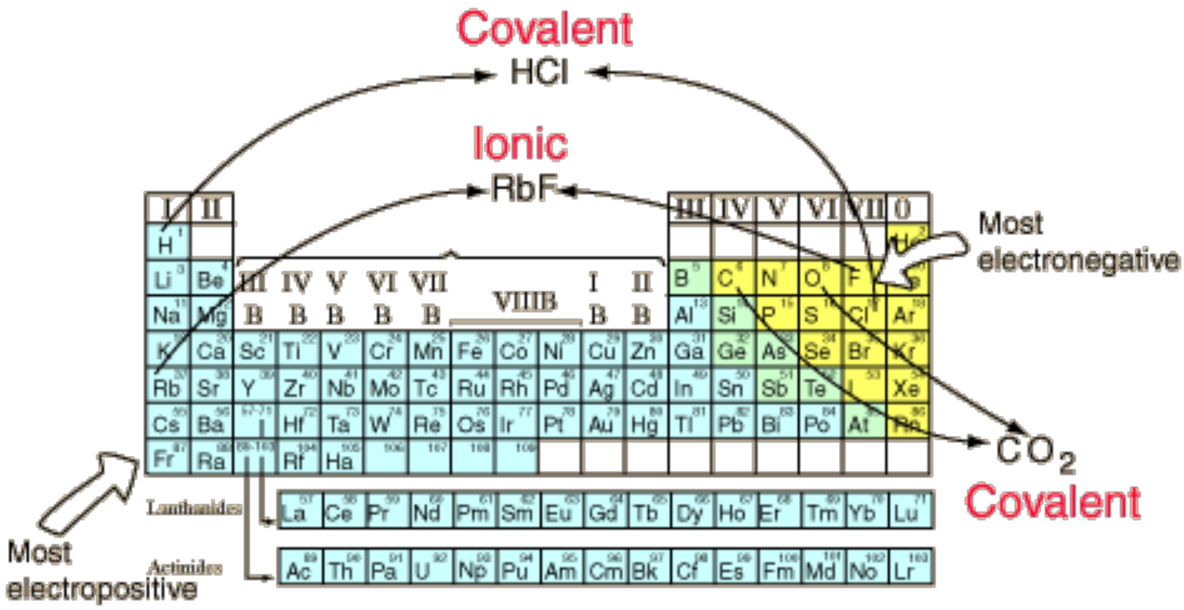
Ionic compounds have regular structures (giant-ionic lattices) in which there are strong electrostatic forces in all directions between oppositely charged ions. These compounds have high melting points and high boiling points because of the large amounts of energy needed to break the many strong bonds.

Comparison of Properties of Ionic and Covalent Compounds

Because of the nature of ionic and covalent bonds, the materials produced by those bonds tend to have quite different macroscopic (large scale) properties.
The atoms of covalent materials are bound tightly to each other in stable molecules, but those molecules are generally not very strongly attracted to other molecules in the material. On the other hand, **the atoms (ions) in ionic materials show strong attractions to other ions in their vicinity**.
This generally leads to low melting points for covalent solids, and high melting points for ionic solids. For example, the molecule carbon tetrachloride is a non-polar covalent molecule, CCl_4. It's melting point is -23°C. By contrast, the ionic solid NaCl has a melting point of 800°C.

	Ionic Compounds		**Covalent Compounds**
1	Crystalline solids (made of ions)	1	Gases, liquids, or solids (made of molecules)
2	High melting and boiling points	2	Low melting and boiling points
3	Conduct electricity when melted	3	Poor electrical conductors in all phases
4	Many soluble in water but not in nonpolar liquids	4	Many soluble in nonpolar liquids but not in water

You can anticipate some things about bonds from the positions of the constituents in the periodic table. Elements from opposite ends of the periodic table will generally form ionic bonds. They will have large differences in electronegativity and will usually form positive and negative ions. The elements with the **largest electro negativities are in the upper right** of the periodic table, and the elements with the **smallest electro negativities are on the bottom left**. If these extremes are combined, such as in RbF, the dissociation energy is large. As can be seen from the illustration below, hydrogen is the exception to that rule, forming covalent bonds. Elements which are close together in electronegativity tend to form covalent bonds and can exist as stable free molecules. Carbon dioxide is a common example.

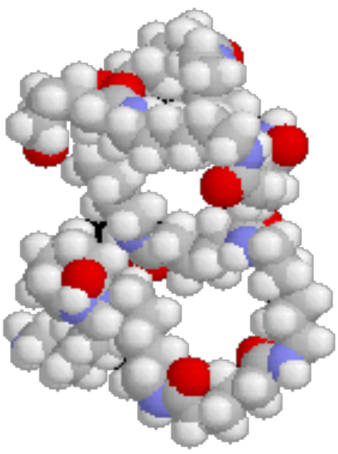


The elements in Group 1 of the periodic table, the alkali metals, all react with non-metal elements to form ionic compounds in which the metal ion has a single positive charge.

The elements in Group 7 of the periodic table, the halogens, all react with the alkali metals to form ionic compounds in which the halide ions have a single negative charge.

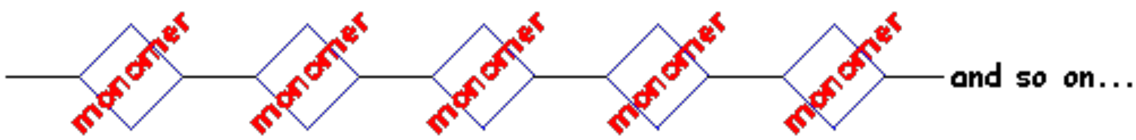
What about polymers? How are they bonded together?

Firstly – what is a polymer?



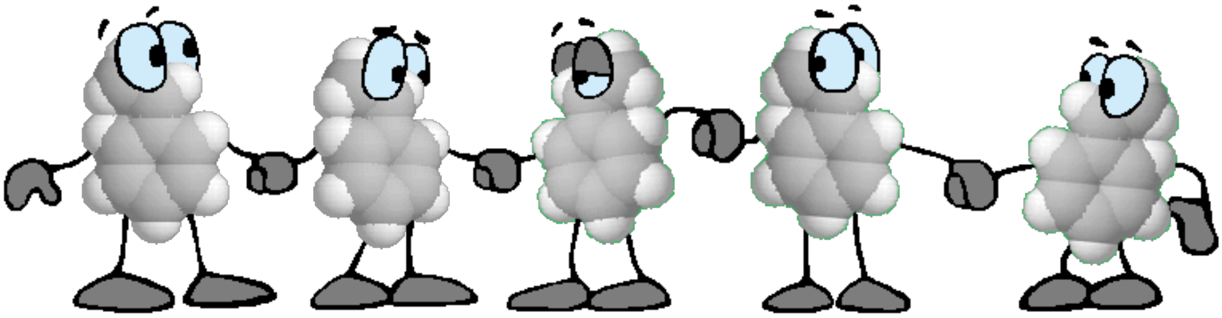
Polymers are made up of many many molecules all strung together to form really long chains (and sometimes more complicated structures, too).
What makes polymers so fun, is that how they act, depends on what kinds of molecules they're made up of and how they are put together. The properties of anything made out of polymers really reflect what's going on at the ultra-tiny (molecular) level. So, things that are made of polymers look, feel, and act depending on how their atoms and molecules are connected, as well as which ones we use to begin with! Some are rubbery, like a bouncy ball, some are sticky and gooey like glue and slime, and some are hard and tough, like a skateboard.

Poly- means "many" and -mer means "part" or "segment". Mono means "one". So, monomers are small molecules that can join together to make a long polymer chain



This is a simple diagram of a chain of monomers.

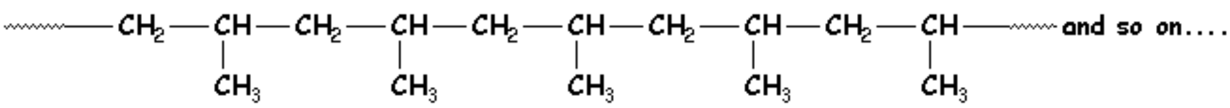
Secondly – How are they bonded together?



Most of the polymers are linear polymers. A linear polymer is made up of one molecule after another, hooked together in a long chain. **This chain is called the backbone.**

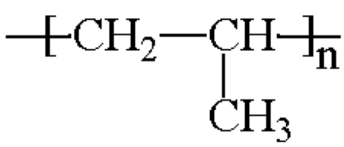
Polymer **backbones are held together by covalent bonds** - by atoms sharing electrons. Other atoms, or even groups of atoms, can hook onto the backbone by covalent bonds and also ionic bonds too.

The atoms that make up the backbone of a polymer chain come in a regular order, and this order repeats itself all along the length of the polymer chain.
For example, look at polypropylene:



Its backbone chain is made up of just two carbon atoms repeated over and over again. One carbon atom has two hydrogen atoms attached to it, and the other carbon atom has one hydrogen atom and one pendant methyl group (CH_3).

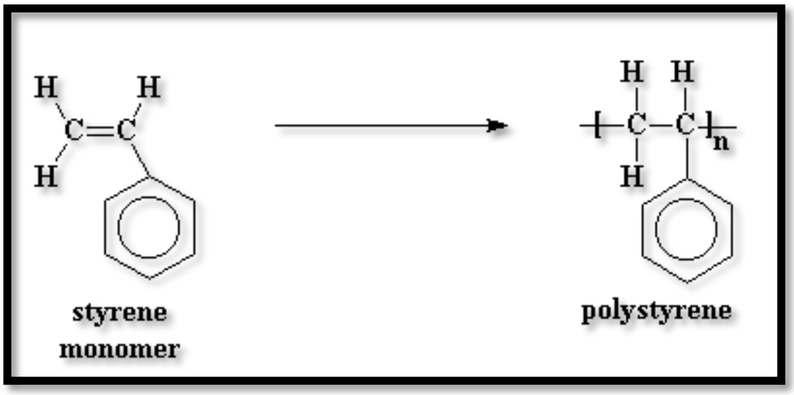
To make things simple, we usually only draw one unit of the repeat structure, like this:



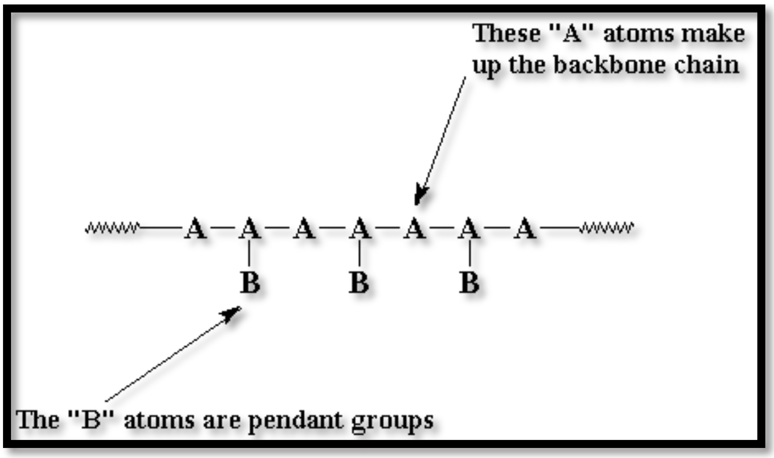
The repeat unit is put inside brackets, and the subscript n just stands for the number of repeat units in the polymer chain.

Another example: styrene monomers join together to make polystyrene- we will look and the environmental impacts of polystyrene as litter later:

Scientific Sue's Litter Lab



As a reminder, a "pendant" group on a polymer is a small group of atoms (even a small chain sometimes) that hangs off of the main chain (that is, the backbone of the polymer).



Pendant groups are much smaller than the backbone chain. Pendant groups normally have just a few atoms (or maybe even a dozen or so), but the backbone chain usually has hundreds of thousands of atoms.

Structure and properties of Polymers

Strong covalent bonds join atoms to each other in individual polymer molecules. Weak intermolecular forces attract polymer molecules towards each other. The properties of solid materials like polymers depend on:

1. ***how their molecules are arranged***
2. ***the strength of the forces***

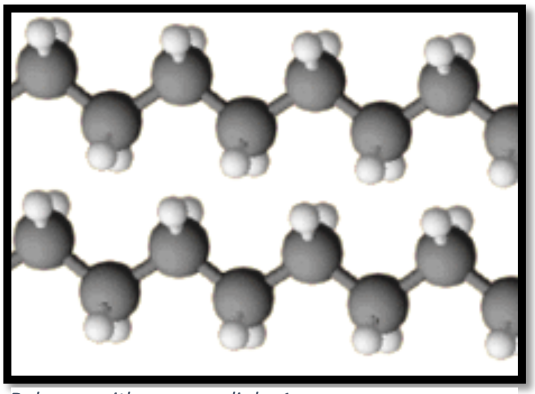
Remember – how the atoms are bonded to each other can have a huge impact on what something made out of those polymers feels like and how it reacts when you bash it or step on it or throw it against the wall – will it stick or bounce off?

A polymer will melt when the intermolecular forces are overcome. The stronger the forces, the more energy is needed to break them, and the higher the material's melting point.

Polymer chains

Many polymers, such as poly(ethene), contain long molecules that lie side by side. These can uncoil and slide past each other, making the material flexible. Long polymer chains have stronger forces of attraction than shorter ones; they make stronger materials.

The properties of polymers depend on what they are made from and the conditions under which they are made. For example, low density (LD) and high density (HD) poly(ethene) are produced using different catalysts and reaction conditions.



Polymer with no cross-links 1

Cross Chain Linking

One of the most well-known natural polymers is poly-isoprene, or natural rubber. Ancient Mayans and Aztecs, in what is now Central America, harvested it from the hevea tree and used it to make waterproof boots and the balls that they used to play a game similar to basketball.

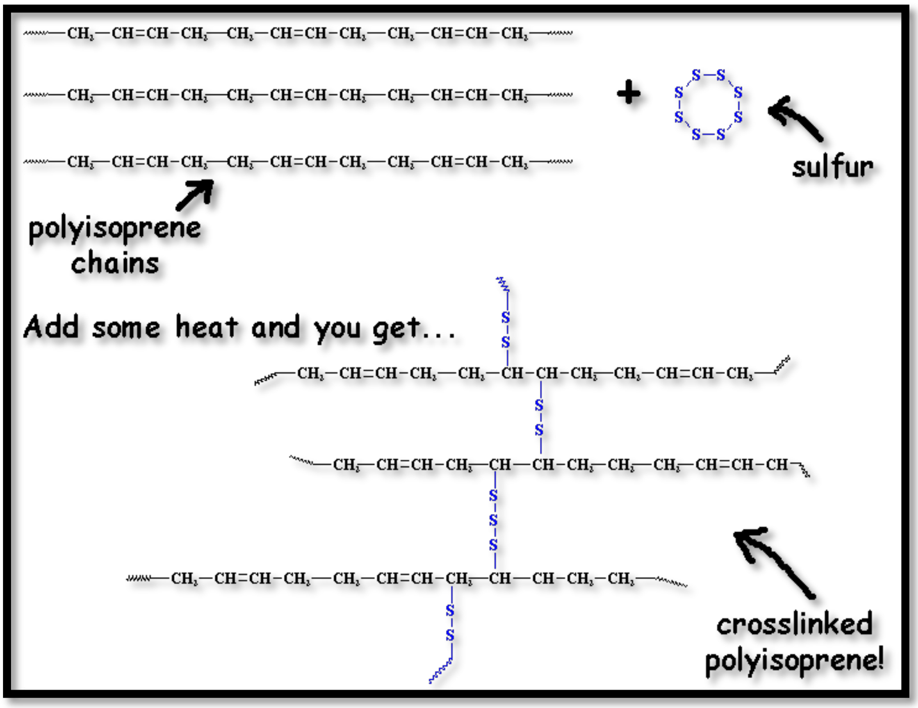
Poly-isoprene is what we call an elastomer, that is, it recovers its shape after being stretched or deformed.

Natural rubber latex coming straight out of the tree, isn't good for much. It gets runny and sticky when it's warm, and it gets hard and brittle when it's cold.

In 1839 Charles Goodyear, a tinkerer and inventor, was trying to make rubber more useful and was not being very successful at that point. While tinkering around in his kitchen with a piece of fabric coated with a mixture of rubber, sulfur, and a little white lead, he accidentally laid it on a hot stove top. It began sizzling and emitting that smell we now know of as burning rubber. When he took a look at this mass of rubber, he found it wouldn't melt and get sticky when it was heated, nor would it get brittle when he left it outside overnight in the cold Massachusetts winter. He called his new rubber vulcanized rubber.
What had happened here? What did the sulfur do to the rubber?

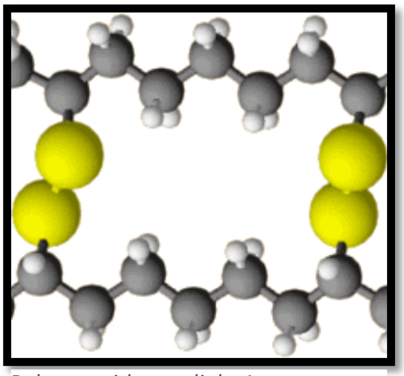
Cross-linking is where the polymer chains are chemically joined together in places, by covalent bonds. The polymer molecules cannot slide over each other so easily. This makes materials tougher and less flexible, and they cannot be easily stretched.

What it did was it formed bridges that tied all the polymer chains in the rubber together. These are called crosslinks.

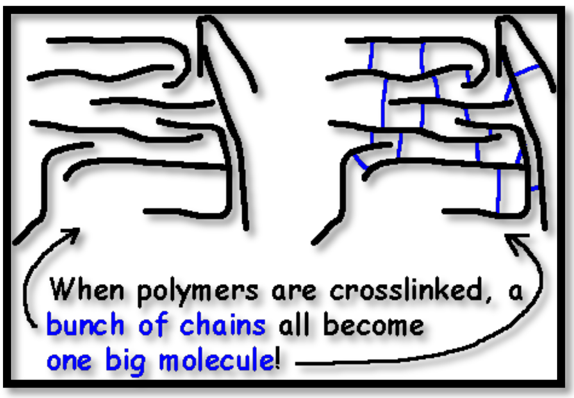


Bridges made by short chains of sulfur atoms tie one chain of poly-isoprene to another, until all the chains are joined into one giant ‘super molecule’. An object made of a crosslinked rubber is in fact one single molecule. A molecule big enough to pick up in your hand!

These crosslinks tie all the polymer molecules together. Because they're tied together, when the rubber gets hot, they can't flow past each other, nor around each other. This is why it doesn't melt. Also, because all the polymer molecules are tied together, they aren't easily broken apart from each other. This is why Charles Goodyear's vulcanized rubber doesn't get brittle when it gets cold.



Polymer with crosslinks 1



Take a look at the bigger picture. The drawing on the left shows the difference between a lot of single un-crosslinked polymer chains, and a crosslinked network.

But rubber isn't the only thing that can be crosslinked. Plastics are also made stronger by crosslinking. Crosslinked polymers are usually molded and shaped before they are crosslinked.

Once crosslinking has taken place, usually at high temperature, the object can no longer be shaped. Because heat usually causes the crosslinking which makes the shape permanent, we call these materials thermosets. They are different from thermoplastics, which aren't crosslinked and can be reshaped once molded. The first thermoset was again poly-isoprene. The more sulfur crosslinks you put into the polyisoprene, the stiffer it gets. Lightly crosslinked, it's a flexible rubber. Heavily crosslinked, it's a hard thermoset.

Crosslinking makes both elastomers and plastics stronger, but there's a problem. Because crosslinked materials don't melt, it's very hard to recycle them. One answer to this problem is to create crosslinks that can be reversed, or undone, believe it or not. One family of materials using reversible crosslinks is thermoplastic elastomers.

Thermoplastic Elastomers

A thermoplastic elastomer is just what the name sounds like, a rubber that acts like plastic. At normal temperatures it is durable and bouncy like most any other kind of rubber, but it can also be melted and easily formed into shapes when it is heated - like plastics.

Many thermoplastic elastomers are like this because they are copolymers made from two different polymers - one a rubber and the other a plastic. Because they can be melted, they are recyclable. But when they are cool they form crosslinks that are not permanent This makes then pretty rubbery.
One pretty common thermoplastic elastomer is SBS rubber which is used to make all the rubber parts on athletic shoes.

Thermosoftening polymers consist of individual, tangled polymer chains. Thermosetting polymers consist of polymer chains with cross-links between them so that they do not melt when they are heated.

Using Polymers to Make Things

1 Slime

Poly vinyl alcohol, PVA (-[$CH_2CH(OH)$]n-), is a polymer that most students will be familiar with as wood glue. By cross linking the polymer chains using Borax (hydrated sodium tetraborate - ($Na_2B_4O_7.10H_2O$) - see CLEAPSS Hazcard)- solution 'slime' is formed in a rapid reaction and produces a material ready for investigation within minutes.

Slimy Encounters
A suggested demonstration for cross-chain linking*

Nuts & Bolts

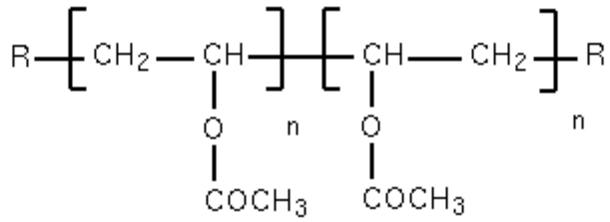
18 white balls
3 lengths of string 40 cm long
8 yellow balls
Velcro hooks and loops
Large clear bowl
Large clear jug
Large darning needle – at least 7 cm in length
Small candle

* Materials available from Science2Life as a kit or fully made-up

- Carefully heat the tip of the needle in the candle flame. Use the heated end to make 2 holes opposite each other on all of the white ping pong balls. This is not required if you get practice golf balls as they are already holey.
- Thread 6 white balls onto each length of string. Tie large knots at each end.
- Cut the Velcro hooks into 8 strips approximately 13cm long and 1 cm wide (they have to be long enough to loop fully around the ball – see diagram) – wrap the strips round the yellow balls. Repeat this process with white balls using the Velcro loops.

Each of the white balls represents a single molecule (a monomer) of polyvinyl acetate, a rubbery synthetic polymer which is most commonly used as an emulsion in water as an adhesive for wood, paper and cloth.

Scientific Sue's Litter Lab



This diagram shows the arrangement of these atoms in two consecutive monomers. Each molecule (monomer) contains 12 atoms: 4 carbon atoms, 6 hydrogen atoms and 2 oxygen atoms.

In PVA the monomers link together in identical, repetitive segments that form long chains of molecules called polymers. The white balls on string are used to represent 3 long chains of PVA glue.

Place them in the bowl, lift the bowl up and move it from side to side; the chains will move and flow over each other but will not stick to each other – an analogy that you might use is; 'if we looked at the long chains of PVA molecules under a microscope they would look like a bowl of spaghetti or worms!' Reach in and grab one chain and pull it out. Hold it up and discuss the idea of monomers and polymers.

Even though the chains don't stick together they do wrap themselves around each other, hence polymer liquids like glue are much thicker than liquid monomers such as water or our borax solution.

Hold up the jug containing the yellow balls – each represents a borax molecule, when the jug is tipped side to side the molecules move freely, just like the molecules in water, they are small molecules and roll over each other just like marbles in a jar. Pour the yellow balls into the bowl of long chain molecules stir briefly with your hand then grab one chain and lift it out; this time it does not come out freely; the whole bunch of molecules come with it.

Borax [$Na_2B_4O_7 \cdot 10H_2O$] is also known as sodium borate, or sodium tetraborate, or disodium tetraborate. It is an important boron compound, a mineral and a salt of boric acid. It is usually a white powder consisting of crystals that dissolve easily in water.

Borax has a wide variety of uses. It is a component of many detergents and cosmetics. It can also be used as an insecticide and as an anti-fungal compound for fiberglass.

SAFETY: **Repeated or prolonged contact with skin may cause dermatitis; if allergic to soaps and detergents it is recommended that gloves be worn.** Refer to your CLEAPSS cards for directions on how to make safe solutions.

Making the PVA

- mix a 4% solution of PVA and water.
- 4 % would be 40 grams of PVA to 960 cm^{3}l of distilled water (of course you can adjust and make more or less). Wear a mask and have plenty of ventilation when doing this! It helps to have a heated magnetic laboratory stirrer (don't use one of your good kitchen saucepans - it's best to use Pyrex lab ware).
- Slowly, gradually, mix the PVA into the distilled water. Heat it slowly, stirring the whole while, until the PVA goes into solution. This will take 15 minutes or more. Do not let it boil. Once cool, the solution can be stored in a stoppered bottle.
- Or commercially bought PVA school/wood glue.

Making the 4% Borax Solution

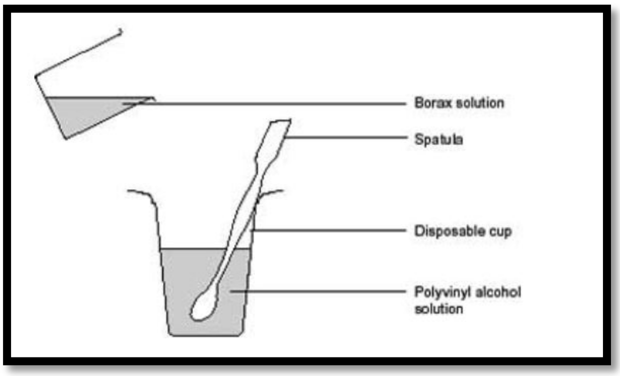
- Dissolve 0.8g of borax in 20 cm^3 of water.
- A small amount of water soluble dye (e.g. fluorescein) or food colouring may be added at this stage.

The borax dissolves in the water to form a weakly alkaline solution and cross links alcoholic OH groups via hydrogen bonds forming a gel like structure. Typically, 96% of the volume is trapped water. The hydrogen bonds are not permanent and this gives rise to the slime properties observed.

Making the slime – Each working group requires:

Apparatus

- Goggles
- Beaker (100 cm^3)
- Measuring cylinder (50 cm^3)
- Disposable plastic cup
- Metal spatula
- Petri dish (or watch glass)
- Water-based felt-tipped pen
- Spirit-based felt-tipped pen
- Disposable plastic gloves



Chemicals

- PVA, polyvinyl alcohol, 4% aqueous solution, 40 cm^{3}l
- Borax, hydrated sodium tetraborate 4% aqueous solution, 10 cm^3
- Food colour or fluorescein (optional)
- Hydrochloric acid, 0.5M, 20 cm^{3}l – (optional)
- Sodium hydroxide, 0.5M 20 cm^3 – CORROSIVE (optional)

Refer to Health and Safety and Technical notes section below for additional information.

Scientific Sue's Litter Lab

Procedure

1 Place 40 cm^3 of the polyvinyl alcohol solution in the plastic cup.
2 Add one drop of food colour or fluorescein dye to the solution. Stir well.
3 Measure out 10 cm^3 of borax solution into the beaker and add this to the polyvinyl alcohol solution, stirring vigorously until gelling is complete. This gel is sometimes known as 'slime'.
4 Wearing disposable gloves, remove the slime from the cup and knead it thoroughly to mix the contents completely. Roll the slime around in your hand, gently squeezing the material to remove air bubbles at the same time. Alternatively, place the slime in a plastic bag and mix and squeeze the mixture from outside the bag.
5 Test the properties of your slime in the following ways. Pull the slime apart slowly. What happens? Pull the slime apart sharply and quickly. What happens? Roll the slime into a ball and drop it on to the bench. What happens? Place a small bit of slime on the bench and hit it hard with your hand. What happens?
6 Write your name on a piece of paper with a water-based felt-tipped pen. Place the slime on top, press firmly, and then lift up the slime. What has happened to the writing and to the slime? Try the same again, this time using a spirit-based pen. Does this show the same effect?

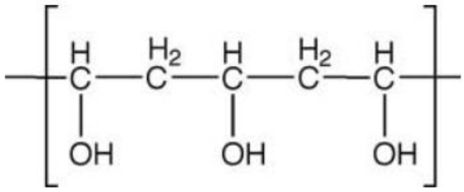
Tests 7–9 below are optional.

7 Place a very small piece of slime in a Petri dish. Add the dilute hydrochloric acid dropwise, stirring well after each drop. When you notice a change record the number of drops added and your observations.
8 Now add dilute sodium hydroxide solution to the same sample used above in 6, stirring after each drop. When you notice a change record the number of drops added and your observations.
9 Can tests 7 and 8 be repeated time and time again to give the same results?

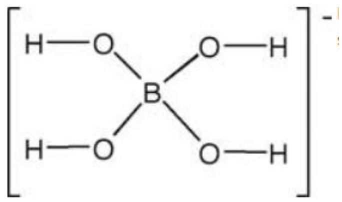
Teaching Notes

Tell students to keep the slime away from clothes as it can produce permanent stains. The slime can be stored in an air-tight container, such as a plastic bag with a twist-tie. It is advisable to dip the slime in some water before storing, to keep it from drying out. Slime gets dirty from handling and may become mouldy after several days. When this happens you should throw it away. Do not put it down the sink because it clogs the drain. Slime-type materials are available under a variety of different brand names, and can be found in many toy stores. Slime is sometimes described as a reversible cross-linking gel. The cross-linking between the polymer chains of polyvinyl alcohol occurs by adding borax, $Na_2B_4O_7.10H_2O$ (sodium tetraborate).

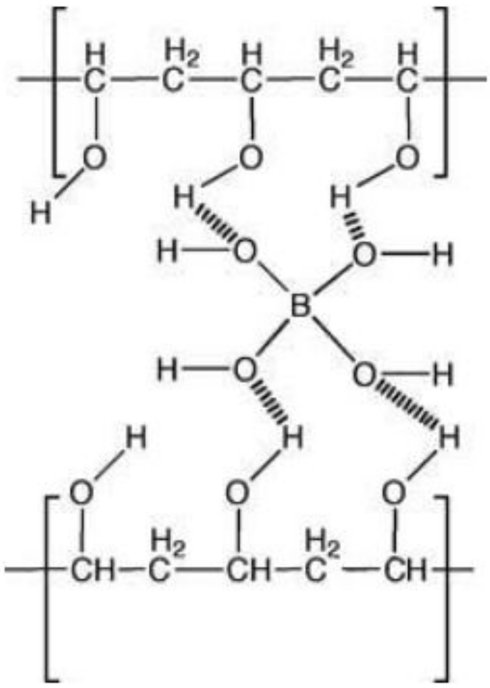
PVA glue contains, amongst other things, the polymer polyvinyl alcohol (also called polyethenol). Polyvinyl alcohol has the structure:



Borax forms the borate ion when in solution. This ion has the structure:



The borate ion can make weak bonds with the OH groups in the polymer chains so it can link the chains together as shown below. This is called cross-linking:



First polymer chain

Borax crosslink

Second polymer chain

Slime is a non-Newtonian fluid that is dilatant – i.e. under stress, the material dilates or expands. Other well-known stress-thickening materials are quicksand, wet sand on the beach, some printer's inks, starch solutions and 'Silly Putty'. Dilatant materials tend to have some unusual properties.

Under low stress, such as slowly pulling on the material, it will flow and stretch. If careful, you can form a thin film.

Pull sharply (high stress) and the material breaks.

Pour the material from its container then tip the container upwards slightly, the gel self-siphons.

Put a small amount of the material on a table top and hit it with your hand, there is no splashing or splattering.

Throw a small piece onto a hard surface; it will bounce slightly.

Adding acid to the slime breaks the crosslinking producing a liquid with lower viscosity. Adding alkali reverses the process and the slime should be regenerated.

Various types of slime have been manufactured. In this investigation you use the polymer polyvinyl alcohol, which is reasonably cheap and is readily available from suppliers because it is widely used as a thickener, stabiliser and binder in cosmetics, paper cloth, films, cements and mortars. In ethanol solution polyvinyl alcohol solution dries to leave a thin plastic film that is useful in packaging materials, especially as it is biodegradable. PVA glue can be partially or completely hydrolysed to give polyvinyl alcohol.

Possible variables to investigate:

- Ratio of PVA to borax – change volume of 4% borax solution added
- Concentration of borax or PVA – dilute/concentrate solutions as appropriate
- Temperature – slime can be placed in a beaker in a water bath until the desired temperature has been achieved
- Affect of pH – this will affect the degree of cross linking and can be investigated by adding borax buffered mixtures

Health & Safety and Technical notes

Wear eye protection, and protective gloves if handling the slime.
Polyvinyl alcohol, (-[CH_2CH(OH)]n-) - PVA can be high Molar Weight (about 120 000) or low MW (about 15 000). If high MW PVA is used, prepare a 4% solution by placing 960 cm^3 of water into a tall 1 dm^3 beaker. Measure out 40 g of high MW PVA and add this slowly to the beaker of water, with stirring. If low MW PVA is used, prepare an 8% solution by placing 920 cm^3 of water into a tall 1 dm^3 beaker. Measure out 80 g of low MW PVA and add this slowly to the beaker of water, with stirring. In each case, heat the mixture gently, stirring occasionally, until the solution clears. Avoid boiling the solution. After cooling, this solution can be poured into suitable smaller containers, which can then be sealed and stored indefinitely.

Borax, hydrated sodium tetraborate, ($Na_2B_4O_7.10H_2O$) - see CLEAPSS Hazcard. If a 4% aqueous solution of PVA is used a 4% aqueous solution of borax will be required. If an 8% aqueous solution of PVA is used an 8% aqueous solution of borax will be required. Borax solid is now classified as TOXIC because it carries the R60/61 warning – it may cause infertility and harm to the unborn child. The solid and solutions in excess of 8.5% should be labelled TOXIC, but other solutions will NOT carry any hazard warning. Borax solutions as prepared following these instructions do NOT require a hazard span. BUT technicians preparing the solutions need to be alerted to the hazard. CLEAPSS advises weighing the solid very carefully, possibly in a fume cupboard which is not switched on. Pregnant women should avoid handling the solid. Students may want to take the slime home - this should not be allowed.

Fluorescein - see CLEAPSS Hazcard and CLEAPSS Recipe Book. Hydrochloric acid, HCl (aq) - see CLEAPSS Hazcard and CLEAPSS Recipe Book. Best supplied in small glass bottles fitted with teat pipettes.

Sodium hydroxide, NaOH (aq), (CORROSIVE) - see CLEAPSS Hazcard and CLEAPSS Recipe Book. Best supplied in small glass bottles fitted with teat pipettes.

Slime - see CLEAPSS Recipe Book. As per the instructions for Borax above the slime is NOT TOXIC but students should not be allowed to take the slime home.

Slimy Encounters!

My Name: ____________________ My number is __________ Date: _______________

You have been organised into groups and numbered 1, 2, 3 or 4. Write your name and the names of your group members in the numbered spaces on all of the worksheets. Now place your worksheets in a **poly pocket** to keep them dry!

1 ______________________		2______________________		3______________________		4______________________	
Ingredient	**Quantity**	**Ingredient**	**Quantity**	**Ingredient**	**Quantity**	**Ingredient**	**Quantity**
PVA Glue	10 ml	PVA Glue	10 ml	PVA Glue	10 ml	PVA Glue	10 ml
Coloured Water	6 ml	Coloured Water	9 ml	Coloured Water	12 ml	Coloured Water	15 ml
Borax Solution	25 ml	Borax Solution	25 ml	Borax Solution	25 ml	Borax Solution	25 ml

Activity 1: For this activity you need: **your slime ball, a pencil and a ruler.**

Slimy Pancakes!	**Name 1** ____________	**Name 2** ____________	**Name 3** ____________	**Name 4** ____________
Form your slime into a ball shape. Place it on the desk. With the ruler measure its diameter. Write measurement under time = 0 minutes. Repeat measurement after 2 minutes and then after 4 minutes. **Remember to put your measurements and your team mate’s measurements in the spaces opposite.**	Time = 0 minutes _______ cm Time = 2 minutes _______ cm Time = 4 minutes _______ cm	Time = 0 minutes _______ cm Time = 2 minutes _______ cm Time = 4 minutes _______ cm	Time = 0 minutes _______ cm Time = 2 minutes _______ cm Time = 4 minutes _______ cm	Time = 0 minutes _______ cm Time = 2 minutes _______ cm Time = 4 minutes _______ cm

Whose slime ball spread out the most? ______________________________

Whose slime ball spread out the least? ______________________________

Discuss your results. Why do your slimes have different properties?

Write your explanation here:

Activity 2: For this activity you will need **a pencil and a ruler.**

The Slime Stretch!	**Name 1** ____________	**Name 2** ____________	**Name 3** ____________	**Name 4** ____________
At the same time as everyone in your group lift up your slime pancake by its edge - see photo. Count to 10 Place it on the desk. Measure its length. Write all 4 lengths on this record page. Lift them up again. Count to 10. Place them back on the desk and measure their new lengths	Length after 10 s _________ cm Length after 20 s _________ cm	Length after 10 s _________ cm Length after 20 s _________ cm	Length after 10 s _________ cm Length after 20 s _________ cm	Length after 10 s _________ cm Length after 20 s _________ cm

Whose slime pancake stretched the most? ______________________________

Whose slime pancake stretched the least? ______________________________

Whose slime is the strongest? Why? ____

Write your explanation here:

Activity 3: For this activity you will need **your slime ball, a pencil and one metre stick per group**

Bouncy Slime?	**Name 1** ____________	**Name 2** _____________	**Name 3** _____________	**Name 4** _____________
Form your slime back into a ball shape by **very gently** squeezing them. Taking it in turns. One of you hold the metre stick vertical and steady on the desk or floor. 0 cm at the bottom One of you lift your slime ball up to the 50 cm mark on the metre stick. A third member of the group has to record the height that the slime ball bounces up to when dropped. If time allows, drop each ball 2 times and average the rebound height. **Record the results of all of your team members in the spaces opposite**.	1st ________ cm 2nd ________ cm Average rebound height ________ cm	1st ________ cm 2nd ________ cm Average rebound height ________ cm	1st ________ cm 2nd ________ cm Average rebound height ________ cm	1st ________ cm 2nd ________ cm Average rebound height ________ cm

Whose slime ball bounced the highest? ______________________________

Whose slime ball bounced the least? _________________________

Scientific Sue's Litter Lab

Design-a-Slime: Notes for Teachers

Activity

		 The 'Slimes' will vary – Slime 1 is the thickest. At the beginning they are all slightly rubbery but as time goes on they will become smoother.
1	Form your slime into a ball. Measure its diameter.	Are there any mathematical relationships between the measurements? Is this experiment a **fair test?** Yes. All other variables have been kept constant – ie same volumes of PVA and borax used; only the amount of water has been changed.
1	Measure the diameter of your slime when it is a flat pancake.	 Your pupils should find that Slime 1 is wider than Slime 2 which is wider than Slime 3. Some may even find a mathematical relationship – when I did this I found the measurements to be 6cm, 9cm and 12cm.
3	Drop your slime ball from a height of 50 cm. How high does it bounce upwards?	**Note Slime is not to be thrown downwards as the force will make it act like a solid and it could break up.**

Slime in Nature:

In the picture you can see a ring of short sensitive tentacles around their mouth

Here is a picture of a **Hagfish:** They look kind of like eels. Their eyes are very small but they have good senses of touch and smell.

Hagfish have large SLIME glands lining their sides along the length of their bodies. When threatened hagfish secrete a huge amount of slime as a defense mechanism.

What kind of tricks can they do?
One very useful trick hagfish have developed is the ability to tie themselves in knots, and be able to slide in and out of this knot. This can be used to escape predators, to clean themselves of slime, and to work their way into a carcass.

They can also sneeze to unclog their nostrils of their own slime!
Google: Slime and Hagfish Find out how scientists use this slime to replace eggs in baking.
The Hagfish is very sensitive to pollution – it is also used as a measure of how healthy the water it lives in is.

2 Making Bubble Gum

Nobody knows who the first person to chew gum may have been. There is plenty of evidence though to suggest that people have been chewing something – lumps of tar, various sweet grasses, leaves, grains, waxes and chunks of white blubber (eek -gross!) – for many, many centuries.

Natural chewing gum can be found as an extract of the tree barks in many areas of the world, especially in Central America where Aztec culture used chicle gum regularly.

Chicle-based gum, derived from the sapodilla tree, was brought to the U.S. in the 1860s, and inspired the gum we know today.

The sapodilla is a slow-growing evergreen native to the forests of Meso-america, including the Mexican states of Veracruz, Oaxaca, Chiapas, Quintana Roo, and Campeche, the Alta Verapaz and Petén regions of Guatemala, northern Belize, and the Atlantic coastal forests of Nicaragua.

Chicle is collected from the tree by cutting into the bark, much like rubber, which causes the tree to excrete it and it runs down the trunk - it can also be extracted from the leaves. When plucked from a branch, the leaves will produce a small amount of latex as a way of protecting the tree from damage by insects or herbivores. This characteristic encouraged the chicle industry to make a minor attempt to increase yields in the 1930s by extracting latex from the leaves, but they produced so little that the experiment was abandoned. Older sapodilla trees are recognizable from the zig-zag marks that were made to extract chicle.

The scars are permanent to the tree. Chicleros, or the extractors, generally mark trees with their own unique symbol so that they can keep track of when a tree was last tapped. Preferably, the trees were left untouched for five years between cuttings to ensure that they would continue to produce latex.

The Native American Indians and Inuit have used gum from the spruce tree to waterproof canoes as well as for chewing. When European settlers came to New England, they adopted the indigenous custom of chewing on spruce tree resin. A New Englander by the name of John Curtis capitalised on the popularity of chewing resin and in 1848 invented the first commercial spruce tree gum called the State of Maine Pure Spruce Gum. Other imitators soon followed, which in addition to the increased demand for spruce wood pulp needed for making newspapers, caused their reserves to shrink.

Another disadvantage to spruce gum was that although it was aromatic, the resin had a bitter after-taste and became brittle after being chewed. By the 1920s, there was only one producer of spruce gum left—Harry Davis, the self-proclaimed "Spruce Gum King," who catered to older customers who wanted to chew their childhood gum. In the place of spruce gum, other small-scale producers prepared gums from ingredients such as beeswax, paraffin (1850's), and saps from the cherry and tamarack trees — and of course chicle, which came about in the 1870s through an inadvertent connection between a New York family by the name of Adams and the exiled former president of Mexico, Antonio López de Santa Anna. The chewing gum industry has created several U.S. millionaires and thousands of jobs across the Americas.

So modern gum products evolved from the chicle-based gum introduced in the early 1860s.

Due to the increased popularity of these products, the demand for chicle rose quickly. But, as chicle-suppliers soon realised, their ability to supply chicle was limited by the trees from which it was derived. The trees needed an average of 4 to 8 years of rest between tappings.

Sap from a spruce tree

When chicle-bearing trees of Central America could not keep up with demand, manufacturers turned to synthetic gum bases to continue their business. Paraffin, originally discovered in 1830, was an option as it is colourless, odourless, tasteless and plentiful, but others kept searching for a better material.

An Ohio dentist used rubber to create a gum product for jaw exercise and gum stimulation. William F. Semple was honoured for this work with the first patent to manufacture chewing gum in December 1869.

Today, gum base is made of man-made latex and divided into 2 major categories, chewing and bubble gum, with the latter having more elasticity. In recent years, nonstick gum bases for chewing and bubble gums have been formulated to satisfy the chewing needs of more consumers.

The ancient Greeks chewed mastic gum (resin contained in the bark of the mastic tree found mainly in Greece and Turkey) for centuries, many used it to help clean their teeth and sweeten their breathe.

Not content to chew on the same old stuff, connoisseurs of chewing gum keep refining their recipes, in the hope of realizing that ultimate dream the Ultimate Chew!

For some individuals (food scientists), experimenting with chewing gum and other food items is a full-time career. Often, food scientists work with experts at marketing their products so that we, the consumer, may learn about the new delights they are creating.

Scientific Sue's Litter Lab

We don't need a lot of fancy equipment to be successful food scientists, just the ingredients and equipment found in our local shops and kitchen cupboards plus lots of the ingredient called 'creativity'!

In this activity you are not only going to create your own homemade chewing gums but also try your hand at designing a custom-packaging that will set your bubble gum creation apart from other recognisable brands.

You are also going to split into 2 groups. One will make gum using gum pellets – Synthetic gum; the other will create a chewing gum using natural ingredients. How will you come up with a fair test to decide which is the best gum?

What is chewing gum made of?

The ingredients in your average stick of chewing gum consists of water soluble sugars and flavours and non-water soluble polymers which remain no matter how long you chew. That's why your gum loses its flavour over time. Your saliva washes it away. The same idea applies to why a stick of gum will go from being rigid to squishy after a couple rounds of mastication.

Whatever doesn't break down in gum consists of polymers and stabilizers – additives that transform the polymer to meet certain characteristics. Like the name suggests, elastomers, the main polymer, derive their name from the elasticity they provide. Plasticisers – like natural paraffin or fatty waxes – as well as modified resins act as stabilisers added to soften and bind the gummy compound together while also giving the substance its proper texture. Gum manufacturers also include **antioxidants** in the mix as a way to keep every chewy morsel from **oxidizing** and hardening on the shelf of your local sweet shop.

The molecular properties of every component dictate the gum's distinct profile, but don't just think in terms of

Hydrogen peroxide (H_2O_2) is an example of a molecule which is a strong oxidising agent.
It is used in everyday life as a means of breaking down coloured compounds, whether in clothes or hair.
Scientific Sue used it in the show mixed with yeast which yielded the oxygen gas used to relight a glowing splint.
An oxidising agent:

1. ***is normally a non-metal or positive ion.***
2. ***cause oxidation reactions to take place.***
3. ***gains electrons from other atoms or ions (is itself reduced)***

Antioxidants come up frequently in discussions about good health and preventing diseases. These powerful substances, which mostly come from the fresh fruits and vegetables we eat, prohibit (and in some cases even prevent), the oxidation of other molecules in the body. The benefits of antioxidants are very important to good health, because if free radicals are left unchallenged they can cause a wide range of illnesses and chronic diseases.

taste. You might be singing chewing gum's praises when you're gnawing away at your favorite brand, but what if you step in someone else's gum while walking down the sidewalk? Or get it in your hair?

We already know scrubbing doesn't help remove chewing gum since the main ingredient to chewing gum does not dissolve in water. However, in 2007 scientists told the world they had engineered chewing gum polymers that can break down with water. They start with a hydrophilic (water loving) polymer that absorbs saliva and helps promote a mushy, yet stable composition that will deteriorate naturally.

Home-made bubble gum: Wash your hands thoroughly – keep everything squeaky clean! Wear an apron or old shirt. Tie long hair back.

Ingredients and tools

- 1/3 cup of gum pellets
- 1 cup of icing sugar
- 1 teaspoon of citric acid*
- 1 tablespoon of flavouring*
- food colouring*
- 2 tablespoons golden syrup
- greased proof paper (A2 size)
- lollipop stick –stirrer
- microwaveable bowl
- microwave – a double boiler could also be used
- large scissors
- strips of aluminium foil or parchment

Scientific Sue's Litter Lab

* you can vary these ingredients to design your own specialised gum.

Instructions

1. Pour half a cup of the sieved icing sugar on to the centre of the greased proof paper and use the stirrer to make a well in the centre.
2. Add gum pellets, citric acid, flavouring and golden syrup to the bowl.
3. Microwave in 10 second bursts until the gum is fully melted. BEWARE AS THIS MIXTURE COULD BECOME VERY HOT AND STICKY – SAFETY GLASSES AND OVEN GLOVES TO BE USED.
4. Add your food colouring at this point - red for strawberry or really throw your customers senses off and use colours not usually associated with the flavour! Mix thoroughly.
5. Carefully pour the microwaved mixture into the central well of the icing sugar.
6. Use the stirrer to start combining the mixture – it will be too hot to use your hands at this stage. This mixture should be kneaded in the same way you would knead bread.
7. When it is cool enough you can start using your hands. Continue using the extra icing sugar until your mixture is quite stiff.
8. While kneading break off a piece of gum and pop it into your mouth. How does it taste? You can make it taste more flavoursome by adding more of your flavour and adjust the gum's sourness or sweetness by adding more citric acid or sugar – be careful not to add too much at once.
9. Continue kneading until the gum is smooth and stiff. After 10-15 minutes, most of the powdered sugar should be used up. The more you knead the gum the better it will be! A lot of kneading will should make your gum extra-chewy. This is another factor which could be investigated!
10. Roll out the gum into a long snake.
11. Cut into individual pieces – roll each one in powdered sugar. Wrap in strips of aluminium foil
12. Now the fun begins – start chewing! Can you blow bubbles with your creation? If so are they small or big? After how many chews doe the flavour start to disappear? Taste your friend's creations.

Natural home-made biodegradable chewing gum

Ingredients

- 1/2 cup of food grade beeswax – cut into 2 cm pieces
- 1 cup icing sugar
- 3 tablespoons of honey
- peppermint or cinnamon extract
- double boiler
- silicone coated spoon or spatula
- silicon candy molds or ice cube trays

Impervious to just about everything save extreme heat, beeswax chewing gum keeps indefinitely without preservatives. Regular gum bases have more elasticity than beeswax, but it doesn't limit its ability to deliver flavour; you can incorporate hundreds of non-traditional flavorings you won't find in traditional gum. Fresh herbs aromatise beeswax gum and release their oils and react with your saliva as you chew, so flavours literally form in your mouth.

Instructions

1. Melt the cup of beeswax in a double boiler (or bring a pot of water to a simmer and set a stainless steel mixing bowl on top of it) making sure it doesn't become too liquefied.
2. When beeswax becomes like goo, start adding honey and stir it.
3. Add flavourings. Beeswax gum goes well with peppermint flavouring however you could also try cinnamon, lemon and licorice. Squeeze about 5 drops of flavouring into the pot with the melted was and honey, and stir well.
4. You can add finely chopped herbs, such as rosemary or mint leaves, to the mixture and for medicinal gum add extra peppermint oil and a few drops of lemon juice.

5. Add the sugar. Stir the powdered sugar into the melted gum base. The mixture should begin to thicken. Taste the gum mixture and more flavourings or powdered sugar if you'd like to increase flavour or sweetness.
6. Pour the gum base into molds. Use candy molds and /or ice cube trays for the gum. Place the molds in the refrigerator to give the gum time to harden.
7. Press the gum pieces out of the mold and wrap each piece in wax paper. Store the gum at room temperature.
8. When flavouring beeswax gum with extracts, 3 parts each pineapple and banana, 2 parts wintergreen and 1 part each cinnamon and clove produces the classic bubble gum flavour!

Scientific Sue's Litter Lab

Gum Facts

- The difference between bubble gum and chewing gum is the gum base. Chewing gum base is a natural gum (chicle) harvested from the sap of a tropical sopapilla tree. It is chewy but it will not blow a large bubble. Bubble gum base is a mixture of starches and polymers made in the laboratory and especially formulated to blow bubbles.
- The action of chewing gum is beneficial. It relieves boredom, eases tension and aids in concentration (a scientific fact!). It also helps pull food particles from between the teeth and freshens the breath.
- A stick of containing sugar has about 10 calories. Sugarless gum has 6 calories.
- Swallowing gum will do no harm.
- The United States is the world's leading gum manufacturer. Bubble gum was invented in 1928 by Walter Diermer, an accountant from Philadelphia.
- On average, a piece of chewing gum costs about three pence, but the cost of removal is about £1.50 per piece!
- Chewing gum takes up to five years to biodegrade.
- Some countries are considering putting a tax on gum to help pay for the clean-up costs.
- In Singapore, chewing gum is banned unless you have a prescription from your doctor or dentist.
- 650,000 metric tonnes of chewing gum were produced worldwide in 2005. How much was produced in 2016?
- 935 million packs of gum are chewed by 28 million people in the UK every year. In other words, almost half the UK population chews one piece of gum per day for 47 weeks of the year.
- 80/90% of chewing gum is not disposed of in any litter receptacle.
- After the Smoking Ban was introduced in Ireland, gum use increased by a staggering 30%.

Bad side of Gum

Unfortunately, the same treat that is good for your teeth is also making an unsightly stain on the environment and harming and killing small animals.

Chewing gum pollution can be seen around the world, from streets to sidewalks to the undersides of furniture we use every day.

Every year, London spends an estimated £2,000,000, equivalent to remove gum from pavements, subway trains, and stations.

Belfast City Councils spend over £100 000 a year!

Scientific Sue's Litter Lab

- **So let's do the maths: How many sticks in a pack? How many packs a year? 80% (minimum) of this amount ends up on the streets of Britain. £1.50 per piece to clean up!!!**

.

Clearly, gum pollution is a global mess that requires the help and attention of engineers to clean up.

Current methods of gum removal, such as blowing steam or chemicals onto the gum, freezing the sticky lump with liquid nitrogen, or scraping it off by hand, have proven to be labour intensive, expensive, and largely ineffective. For these reasons, researchers at Revolymer Ltd, a UK-based company with focus in polymer technology, have developed a new kind of gum that can be easily removed from all surfaces without any additional solvents.

Rev7 Gum is a chewing gum, which after chewing **is to some extent removable and biodegradable.** The idea behind the gum's composition was developed by Professor Terence Cosgrove at the University of Bristol and it was developed by the British company Revolymer.

Rev7 is designed to be a low adhesive gum that, unlike conventional gum, can be easily removed from a variety of surfaces, and which degrades and disperses over a short time-scale when in contact with water.

Conventional chewing gums use poly(styrene-co-butadiene) or poly(ethylene-co-vinylacetate). In contrast, Rev7 Gum contains an amphiphilic material, containing both hydrophobic (water repellent) and hydrophilic (water attracting) regions, which aids in the degradability and removability of the substance. It is composed of a polyisoprene backbone and grafts of poly(ethylene oxide) (PEO).

The polymer was developed at the University of Bristol in an effort to curb pollution issues, due to regular chewing gum, which are prevalent in the United Kingdom. Britain spends over £150 million annually (as of 2008) on gum cleanup efforts, using techniques such as high pressure steam hoses, corrosive materials, and freezing machines to help remove this synthetic material from sidewalks and other public spaces.

Its name is derived from the word "revolution" (Rev), and the number attempts it took to achieve the degradable gum (7). Rev7 has two flavours: Natural Peppermint and Natural Spearmint.

If you chew gum, please ensure that you put it in a bin. If there is no bin available, wrap it in a piece of paper and wait until you do find a bin.

Chew it! Wrap it! Bin it!

Can you come up with an advertising campaign to help educate people about disposing chewing gum responsibly?

Purpose - campaign can be adapted to include all litter.

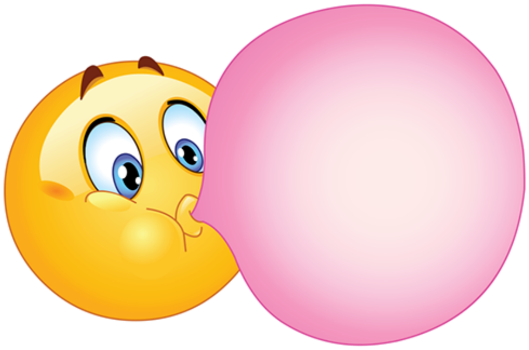
Explain why litter (including chewing gum) is a big problem i.e.

- *Environmental impacts* – dangerous to animals and us, waste not dealt with properly,
- wasted energy & resources could the gum be recycled –Gum Drop
- *Social Impacts* – makes a place look bad, encourages anti-social behaviour
- *Economic Impacts* – costs lots of money to clear up, money that could be spent on other things
- *School Specific* – makes the school look bad, poor reputation in community, costs money to clear up

Challenge some common Myths

I'm giving people a job – litter picking is usually just one duty of many for waste operatives, means they can't be working on something more productive, the money could be spent employing staff for more productive roles
Dropping food is not littering it's feeding the animals/it decomposes – main animals feeding on food litter are rats, foxes & pigeons etc. Litter is not their natural diet and is bad for them, food waste still takes a while to break down – would you think it was ok if people chucked food/banana peels etc. in your garden?

Marketing your 'Biodegradable Bubble Gum'



Think about your gum's flavour and appearance. What words come to mind? Try to name the way your feel when you taste your gum.

Brainstorm a catchy name and logo for your product.

Draw your new logo. What colours will you use to catch your customer's eye? How will you design your custom logo? By hand or using a computer?

Tape or glue your logo to the parchment or aluminium foil before the gum is wrapped.

Chomp Chomp Food Inc. – Marketing Plan

You own a marketing firm that specialises in developing marketing plans for a variety of products. **You've been hired by Chomp Chomp Food to develop a marketing plan for a new product:**

Biodegradable Bubble Gum!

Chomp Chomp Food is based in Belfast, County Antrim, Chomp Chomp has manufactured Food products in the UK and Ireland, and sold Food products to various retailers in the UK and Ireland such as Tesco, Savoury Food, and The Food Authority.

- Each team and each individual will be responsible for coordinating, delegating, and ensuring deadlines are met.
- Find ways of organising, contributing and assisting each other
- Use your resources based on talent and interest. Feel free to re-assign internal resources as needed. You are making one group presentation– not a series of individual presentations. Practice – as it will show if you don't.

The marketing plan had been broken down into a series of tasks. There may be some overlap – so it'll be up to you as to how you want to present your findings.

Scientific Sue's Litter Lab

1. Your plan should address the business' **Target Market and the 4Ps**. (Place, Product, Promotion, & Price)

TARGET MARKET

Product

- What does the customer want from the product?
- What features does it have to meet these needs?
- How and where will the customer use it?
- What does it look like?
- What size(s), colour(s), should it be?
- What is it to be called?
- How is it branded?
- How is it differentiated versus your competitors?

Price

- What is the value of the product or service to the buyer?
- Are there established price points for products or services in this area?
- Is the customer price sensitive?
- What discounts should be offered to trade customers?
- How will your price compare with your competitors?

Place

- Where do buyers look for your product or service?
- If they look in a store, what kind?
- How can you access the right distribution channels?
- Do you need to use a sales force?
- What do your competitors do, and how can you learn from that and/or differentiate?

Promotion

- Where and when can you get across your marketing messages to your target market?
- Will you reach your audience by advertising in the press, or on TV, or radio, or on billboards?
- When is the best time to promote?
- How do your competitors do their promotions? And how does that influence your choice of promotional activity?

2. Your plan should include some element of **Market Research** – whether it is primary or secondary. You should explain what data was collected, how it was collected, its analysis and any conclusions/recommendations based on it.

3. Your plan should consist of specific marketing recommendations based on your plan that address Target Market, 4Ps, and Market Research.

In small groups, you will present your marketing plan to the CEO of Chomp Chomp – Mr. George. You will be evaluated on the quality and comprehensiveness of your marketing plan and your interesting sales presentation. Using the framework below, you need to:

Framework for Presentation

- Choose the name of your product. Be creative.
- Develop a slogan or tagline for the product
- Identify your target market. Consider the following:
  - Demographics (age, gender, income, occupation)
  - Psychographics (lifestyles, leisure time)
  - Geographics (town, county, state, region, country, etc.)
  - Consumer behaviours

- Explain your **product** strategies and decisions
  - Packaging, product benefits, special features that will set this product apart from its competitors, etc.
- Explain your **place** strategies and decisions
  - Chomp Chomp has historically been a manufacturer and wholesaler (distributor). What is going to be the distribution strategy to get this new product into the hands of consumers? (think about practicality, efficiency, and cost when considering the best distribution strategy).
- Explain your **price** strategies and decisions
  - Demand-based, cost-based, competition-based, combination, etc.
  - psychological pricing strategies
- Explain your **promotion** strategies and decisions
  - **What's your message and how will you communicate it?**
  - How and in what format will you reach your customer?
  - Print, broadcast, special events or sales promotions, etc.
  - Describe any advertisements

Remember, the more defined your target market, the easier it will be to figure out how to reach them. **All marketing decisions should be made with the target market in mind.**

Scientific Sue's Litter Lab

Marketing Plan for Chomp Chomps' Biodegradable Bubble Gum –300 Points **Possible Mark Schemes**

Name: ____________________________________

Presentation					
Task	**Beginning**	**Developing**	**Focused**	**Exemplary**	
Content –Major sections (Target Market & 4Ps, Market Research)	Content is unacceptable or missing. **(O Points)**	Few sections are completely addressed in a superior manner. Few sections are organised & well thought out. **(60 Points)**	Most sections are completely addressed in a superior manner. Most sections are organised & well thought out. **(80 Points)**	All sections are completely addressed in a superior manner. All sections are organised & well thought out. Comprehensive report. **(100 Points)**	100
Actual presentation/ Presentation of Content	Did not present to class or very poor communication of presentation. Enthusiasm and interest level was absent from presenters. Maintained unacceptable level of eye contact and voice volume. Confidence was missing from presentation. **(O Points)**	Communicated few aspects of presentation to class. Displayed little enthusiasm during the presentation. Maintained unacceptable level of eye contact and voice volume. Need to develop confidence. **(60 Points)**	Communicated some aspects of presentation to class. Displayed some enthusiasm during the presentation. Maintained acceptable level of eye contact and voice volume. Fairly confident presentation. **(80 Points)**	Clearly communicated all aspects of presentation to class. Displayed enthusiasm during the presentation. Maintained exemplary eye contact and voice volume. Confident presentation. Communicated content of report effectively. **(100 Points)**	100
Duration	Less than 7 minutes **(O Points)**	7-10 minutes **(60 Points)**		10+ minutes **(100 Points)**	100
Total					**300**

Scientific Sue's Litter Lab

Name: ____ **Marketing Plan for Chomp Chomps' Biodegradable Bubble Gum –150 Points**

Report & Content					
Task	**Beginning**	**Developing**	**Focused**	**Exemplary**	
Typed, structured, well written, grammar, spelling	No report was submitted. Final report is unacceptable. **(O Points)**	Few parts of report are structured or well written. Many grammar and spelling errors. Amateur look. Doesn't look very professional. **(3O Points)**	Most parts of report are structured or well written. Few grammar and spelling errors. Could've looked more professional. **(4O Points)**	Report is typed, well structured, well written, with no grammar and spelling errors. Very professional look. **(5O Points)**	50
Content – Major sections (Target Market & 4Ps, Market Research)	Content is unacceptable or missing. **(O Points)**	Few sections are completely addressed in a superior manner. Few sections are organised & well thought out. **(60 Points)**	Most sections are completely addressed in a superior manner. Most sections are organised & well thought out. **(80 Points)**	All sections are completely addressed in a superior manner. All sections are organised & well thought out. Comprehensive report. **(100 Points)**	100
Total					**150**
				Presentation, Report and Content: Overall Total	**450**

Scientific Sue's Litter Lab

Scientific Sue's Litter Lab

Facts about Styrofoam Litter

Styrofoam is mainly used for food packaging (excellent heat insulating properties) or as a cushioning material in packaging.

Packing peanuts are small pieces of Styrofoam that are designed to cushion products, such as electronics, during shipping to prevent any damage. Larger pieces of Styrofoam are also used as they can be easily custom shaped to fit the goods being shipped.

Styrofoam is expanded polystyrene foam. Due to the fact that 95% of Styrofoam is air this material is extremely light; hence the majority of Styrofoam which is littered ends up in the marine environment.

Most of the litter is due to people just throwing their fast food packing away after they have finished eating. Some is caused by the wind lifting lightweight materials out of garbage bins which have not had their lid put on or bins which have been over filled.

When litter is dropped it can be carried from the streets to go down through the storm drains and then out to the ocean and lakes.

★★★★★★★★★★

Styrofoam eating worms

Recently scientists have discovered that mealworms, the larvae form of the darkling beetle, could digest and live healthily on a diet of Styrofoam. About 100 mealworms could consume between 34-39 milligrammes of Styrofoam in a day. The dropping of mealworm was also found to be safe for use as soil for crops.

★★★★★★★★★★

All plastics, including Styrofoam, break down into smaller and smaller pieces and marine animals easily mistake polystyrene for food.

Many seabirds are dying of starvation with stomachs full of plastic.

Styrofoam should not be burned as it releases styrene gas which is harmful to humans and other animals so how should we dispose of it? Many countries are now banning the use of Styrofoam.

Carry out some research and find out why. What could we use in its place? Why are we not using alternatives now?

Greenpeace August 2016 1

Vanishing Peanuts!

Nuts and Bolts
Box of Styrofoam packing peanuts
Handful of cornstarch packing peanuts
2 jars with lids
Large glass bowl
Acetone – See CLEAPPS for guidance
Any other type of Styrofoam e.g. cup

Preparation:
Fill the 2 jars halfway with water
Fill the glass bowl to half way with acetone

Secrets for Success
Show your pupils the Styrofoam and corn-starch packing peanuts.
Ask them what they might be used for.
Ask them what they think will happen when they are placed into the jars of water.

Bring up 2 of your pupils and ask them to fill their jars with the packing peanuts; one with Styrofoam ones and the other with cornstarch ones. Have them screw on the lids tightly and then shake them.

Did they float or sink?
Did they dissolve?

The Styrofoam packing peanuts do not dissolve – Styrofoam is not biodegradable. It will not break down in water and it will sit in landfill sites for many many years – remember what Scientific Sue said in The Litter Lab Show: **If it is not biodegradable it is not digestible**. What is the effect on our wild life and marine life due to them mistaking Styrofoam for food?

The cornstarch peanuts on the other hand dissolve easily in water and naturally decompose in landfills.

Since the Styrofoam did not dissolve in the water how can we break it down?

Lift up the bowl with Acetone. Let your pupils know that is a very special chemical. Show them a container filled with Styrofoam packing peanuts – at least twice the volume of the bowl.
Ask them how many of the packing peanuts they think you will be able to put into the bowl.

Take down some numbers… start pouring in the peanuts. **They will all disappear!**

Did anyone guess the entire container load?

Take a stick of Styrofoam or a fast food dish or container… put it into the bowl. It disappears too!

Science in a Nutshell

Styrofoam is one of the most popular products used for packaging and shipping. It is used all over the world.

Dissolving the Styrofoam in the Acetone shows that Styrofoam has very little actual material to it. Styrofoam is actually 95% air and 5% polystyrene. When added to the Acetone the material breaks up and releases all of the air. The polystyrene sinks to the bottom of the container.

Dissolving Styrofoam or other polystyrene products in acetone is a spectacular demonstration of the solubility of this plastic in an organic solvent, plus it illustrates beautifully how much air is in the Styrofoam.

Acetone is used to remove gel nail varnish so can be purchased from a pharmacy. Acetone $(CH_3)_2CO$ is a translucent flammable liquid and many compounds are soluble when exposed to it.

Styrofoam is one of our biggest concerns environmentally. It is used so broadly and so carelessly that our landfills will be full before we know it. Plus, because it is so light if not disposed of properly it is easily blown into our countryside and oceans.

If you need to send parcels reuse your stored Styrofoam packing peanuts or better still use cornstarch ones.

Find out which businesses near you use packing peanuts. Will they accept donations from the locally community? If so organise a whole school collection. The more that is reused the less will end up as litter.

Smart Colours

Technology

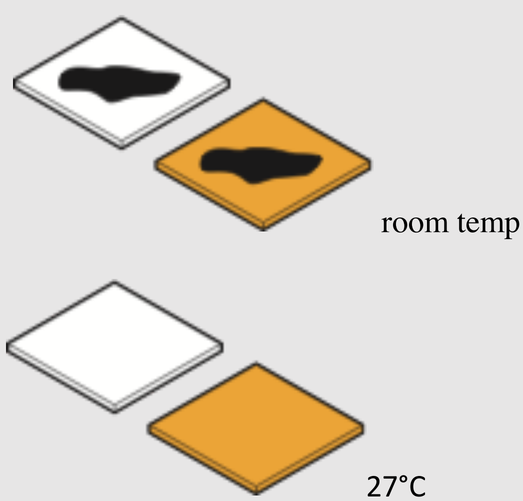
Everyone's heard the phrase "red hot," but what does it actually mean? If you heat an iron bar in a furnace, you'll see it slowly changes colour from its original gray-black (at about 600°C) to red hot (~950°C), yellow hot (~1100°C), and then white hot (at higher temperatures still). The hotter it gets; the more energy it contains. As the fire pumps energy into the iron, the iron 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**.

Sometimes we want things to change colour as they get hotter or colder just for novelty or entertainment. Maybe you've already seen those coffee cups with hidden messages or pictures that suddenly appear, like magic, as you fill them with hot water? Or maybe you have a T-shirt or a poster that changes colour when you touch it? Things like this are printed with special temperature-sensitive dyes (or inks) called **leuco dyes**, which start off transparent (or have a particular colour) and become visible (or change to a different colour) as the temperature rises or falls. The battery test strip is a good example. If the battery is in good condition, current flows through a printed resistor under the thermochromic film and heats it to cause a colour change.

The Principle...

At normal room temperature the pigment appears coloured, but at 27°C the colour disappears. For example, if black thermochromic pigment is applied to a white surface, the surface turns from black to white at the change-over temperature. Similarly, if the pigment is applied to something orange the surface colour changes from black to orange at 27°C. When the temperature falls, the pigment colouring re-appears.



Scientific Sue's Litter Lab

Leuco dyes are organic (carbon-based) chemicals that change colour when heat energy makes their molecules shift back and forth between two subtly differently structures—known as the leuco (colourless) and non-leuco (coloured) forms. The leuco and non-leuco forms absorb and reflect light differently, so appear very different colours when printed on a material such as paper or cotton.

Most thermochromic materials are based on liquid crystal technology. At specific temperatures the liquid crystals re-orientate to produce an apparent change of colour. The liquid crystal material itself is micro-encapsulated, i.e., contained within microscopic spherical capsules typically just 10 microns in diameter. Billions of these capsules are mixed with a suitable base to make thermochromic printing ink or, for example, with plastics destined for injection molding.

In the show Scientific Sue used mixed a thermochromic pigment with an acrylic medium – this was then painted on one of Belfast City Council's Litter Posters. The blow torch was then used as the heat source allowing the colour-change effect to take place thus making it look as though the graffiti had been cleaned.

Within the classroom you can use smart colours on plastic cups – the colour disappears when warm water is poured into the cup.

Pigment painted onto plastic cup

Warm water

Cool water

The thermochromic pigments can also be mixed with acrylic paints of different colours. For example, if blue pigment is mixed with yellow acrylic paint, the resulting colour is green. However, at 27°C, the blue hue disappears and the green changes to yellow! There are of course and infinite number of possible colour variations

Smart Pens – FriXon by Pilot

The secret behind the magic is in Pilot's proprietary FriXion ink. The ink uses three types of chemical compounds that rely on acid-base and temperature sensitivity:
1) special types of dye that change color upon reaction with acids;
2) compounds that act as acids to produce the color change; and
3) compounds that regulate the temperature at which the color transition will take place.

When you rub the ink with the hard rubber eraser, heat from the resulting friction causes the temperature-sensing compound to activate the acid compounds, thus neutralizing the dye. That's how they make the ink virtually disappear!

To speed up the disappearing process Scientific Sue gently waved a flame behind the image of the bubble gum boy to reveal the secret message hidden under the tee-shirt.

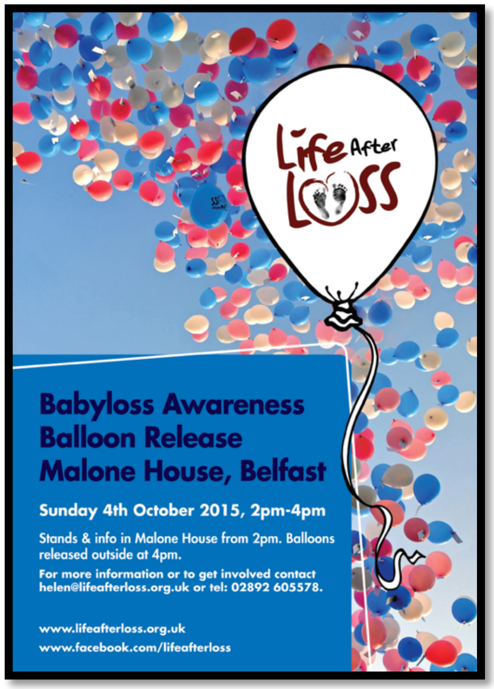
The image can be recovered it the paper is cool the image to temperatures below 10 C.

Even if you tend to write with a heavy hand and create indents on the paper, the ink will erase so long as heat is able to reach it. The erased sections can be written over and erased as many times as needed. Because of its heat-reacting properties, the ink may reappear when temperatures reach below -10 C. It's best to not leave the ink out in hot cars or other conditions that may subject it to vigorous friction, or it may disappear. We also don't recommend writing on the back of page when using these pens, because the heat may transfer to the other side, causing unwanted erasing.

BALLOON RELEASING IN BELFAST

There are two different forms of balloons used in balloon releasing. The first is 'foil' or 'Mylar' balloons, which are not biodegradable and are rarely used. The second type is a helium filled latex balloon which is made from natural products that will eventually decompose. Millions of helium filled latex balloons are released in to the atmosphere each year. Whilst balloon releases pay a very important role in businesses and promotional events, the environmental impacts of balloon releases need to be considered further.

Once a balloon has been released it rises to a height of 5 miles where the pressure and the temperature cause the balloon to undergo brittle fracture. This means the rubber shatters along the grain boundaries of the crystallised segments to give smaller fragments roughly the size of a coin. The small pieces then float back down to earth where they are scattered over the land and sea. It is estimated that there is one piece every 5 square miles. These will look like food to wildlife. Around 5% of the balloons released will be flawed or develop leaks and will not reach an altitude high enough to burst. Thus they then return to the earth intact in an intact state and can have a larger detrimental effect on the environment and the wildlife that live in it.



Positive aspects of balloon release

Research has shown that balloons are able to decompose within 6 weeks. This is a similar time to that taken by an oak tree leaf.

Balloon releasing plays a very important role in prompting and raising funds for charities and other nonprofit organisations through highly visual advertising and social events. In addition, many people rely on balloon releases and other associated activities for their income. For example, balloon manufacturers, helium suppliers, balloon wholesalers and retailers and their employers. Often family run businesses are involved in balloon deliveries and decorating.

Helium filled latex balloons are essentially a completely natural product. The balloons are made from the *Hevea brasisiensis* tree and thus decompose in the same natural manner as the Hevea tree – the same rubber used to make our bubble gum!

Negative aspects of balloon releases

A report by Beachwatch in 2003 has estimated that there are around 8.7 balloons per square km of beach in Britain. However, this figure may be higher in extreme cases, for example 63 balloons were found in a one-mile stretch of beach in Balmedie near Aberdeen. In addition, research has shown that the number of balloons and balloon pieces on Britain's beaches has almost tripled in the last 10 years. This suggests that if balloon release is continued unregulated the negative environmental impact will escalate.

The 5% of balloons that do not burst in the atmosphere are able to travel at least 75 miles. This means that balloons released in Belfast are definitely able to reach the sea, where they are able to cause more damage as they have a slower decomposition rate of over one year.

Often the attached strings and ribbons take longer to decompose than the balloons and can entangle animals and cause internal problems if swallowed. Species found to have ingested balloons include the Common Dolphin, Risso's Dolphin, Loggerhead Turtle, Leatherback Turtle, Sea Turtle, Blue shark, Northern Fulmar and Sperm Whale. In total more than 265 species of birds, fishes, mammals and marine turtles, including endangered and threatened species, are at risk of ingesting marine debris (Coe & Rodgers, 1997). Often animals such as sea turtles will mistake balloons floating in the water for prey, such as jelly fish. Most leatherback turtles washed up on UK shores have digested litter in their gut (Shaver & Plotkin, 1998). In 2001 a green turtle washed up on shore had its stomach blocked by plastic litter and a balloon (Penrose, 2002). Swallowed balloons may cause choking and can block digestive and respiratory systems. Digested food can then not pass through the system and there will be a toxic build up in the animal. Additional nourishment will not be taken in and the animal will slowly starve. This has been proved in marine animals however less research has been done on the impact of the balloon ingestion on land mammals, but a risk to livestock and other creatures of

inadvertently consuming latex balloons still exists. Although most the balloons shatter, the small pieces could still be misinterpreted as food by many of the smaller mammals, causing as much of a problem as the whole balloons do to larger animals. In 1985, an infant sperm whale was found dead of starvation as a result of ingestion of an inflated Mylar balloon which had been lodged in its intestines. A study by Lutz (1990) showed that turtles passed multiple pieces of balloon bound together, although they had ingested the individual pieces at different times. This shows the possible cumulative effect of ingestion of latex balloon pieces. The study also concluded that sea turtles have a feeding preference to brightly coloured balloons over other items such as clear plastic. In addition, other research has shown that they do not pass through the digestive tract of a turtle in the normal time, but have been proven to accumulate and may take up to 4 months to pass through (Caribbean Conservation Corporation (CCC) and Sea Turtle Survival League).

There is also of whether balloon release is legal, as fallen balloons will become litter which is against the Environmental Act of 1990.

Balloons are also able to enter marine systems, for example boats and jet skis, and pose a threat to human safety.

Whilst balloons are able to decompose as fast as oak leaves, often oak leaves can take up to 4 years to completely decompose under natural conditions. Hence balloons can also take up to 4 years to fully degrade, in which time balloons pose a more significant threat to animals then oak leaves. And it is also known that the latex balloons take even longer to degrade when at sea.

The Marine Conservation society, the RSPCA, the Keep Northern Ireland Beautiful and the National Farmers Union, share the view that balloon releases should not occur in the UK given the evidence for the harm that they cause to wildlife and the aesthetic damage to the environment. The Civil Aviation Authority also need to be informed if a balloon release is planned as it can cause problems to air traffic.

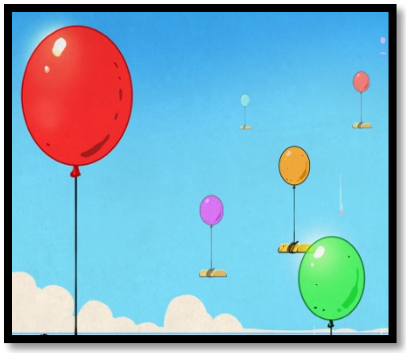
Alternatives

If a balloon release does take place, there are many measures that can be taken to reduce the environmental impact. These are listed below:

5 Use balloons made of natural rubber latex rather than mylar balloons.
6 Always hand tie balloons rather than using plastic valves.
7 Use string and labels which degrade at least as fast as the balloons.
8 Clear balloons degrade fastest (Burchette 1989) and are less tempting to animals.
9 Only release individual balloons rather than clusters. There are also more environmentally friendly events that can be held that still involve using balloons and the associated business. When balloons are used indoors, all the pieces can be collected and safely disposed of. Some of these are mentioned below:
5 Prize balloon popping. – Air fill balloons, and hide prize tickets inside. Release the balloons indoors and have everyone pop then to fine the prizes.
6 Guess the number of balloons. – Run a competition before the balloon popping, the closest guess wins.
7 Balloon Art. – Hire a balloon artist, or for the big, bold statement try a giant air filled balloon sculpture, or balloon statues.
8 Balloon relay. Each member of a team has to run a short distance and sit on a balloon to pop it before running back to tag the next member of the team. The first team to pop all the balloons wins. Alternatively have lines of people pass a balloon to each other by their knees, the first team to get successfully to the end wins.
9 Plant a tree. - Often balloon releases are used for commemorative occasions. Instead plant a tree, shrub or flower garden in memory of loved ones. This will not only leave a lasting memory but provide a haven for wildlife.

Let's look at the Science:

Why do balloons filled with helium float?



Most of us feel comfortable with the idea of something floating in water. We see that happen every day. In fact, people themselves float in water, so we have a way of directly experiencing water flotation. The reason why things float in water applies to air as well, so let's start by understanding water flotation.

Let's say that you take a plastic 1-litre soda bottle, empty out the soft drink it contains, put the cap back on it (so you have a sealed bottle full of air), tie a string around it like you would a balloon, and dive down to the bottom of the deep end of a swimming pool with it. Since the bottle is full of air, you can imagine it will have a strong desire to rise to the surface. You can sit on the bottom of the pool with it, holding the string, and it will act just like a helium balloon does in air. If you let go of the string, the bottle will quickly rise to the surface of the water.

Helium balloons work by the same law of **buoyancy**. In this case, the helium balloon that you hold by a string is floating in a "pool" of air (when you stand underwater at the bottom of a swimming pool, you are standing in a "pool of water" maybe 2 m deep -- when you stand in an open field you are standing at the bottom of a "pool of air" that is many kilometres deep). The helium balloon displaces an amount of air (just like the empty bottle displaces an amount of water). As long as the helium plus the balloon is lighter than the air it displaces, the balloon will float in the air.

It turns out that helium is a lot lighter than air. The difference is not as great as it is between water and air (a litre of water weighs about 1,000 grams, while a litre of air weighs about 1 gram), but it is significant. Helium weighs **0.1785 grams per litre**. Nitrogen weighs 1.2506 grams per litre, and since nitrogen makes up about 80 percent of the air we breathe, 1.25 grams is a good approximation for the weight of a litre of air.

If you put helium in a balloon and let go of the balloon, the balloon rises until it pops. When it pops, the helium that escapes, has no reason to stop -- it just keeps going and disperse out into space.

Therefore, in the atmosphere there is very little helium at any given time. The helium that is there comes from **alpha particles** emitted by radioactive decay. In places that have a lot of uranium ore, **natural gas** tends to contain high concentrations of helium (up to 7 percent). This makes sense, since the decay of uranium emits lots of alpha particles and a natural gas pocket tends to be a sealed container underground. Helium is cryogenically distilled out of natural gas to produce the helium we put in balloons.

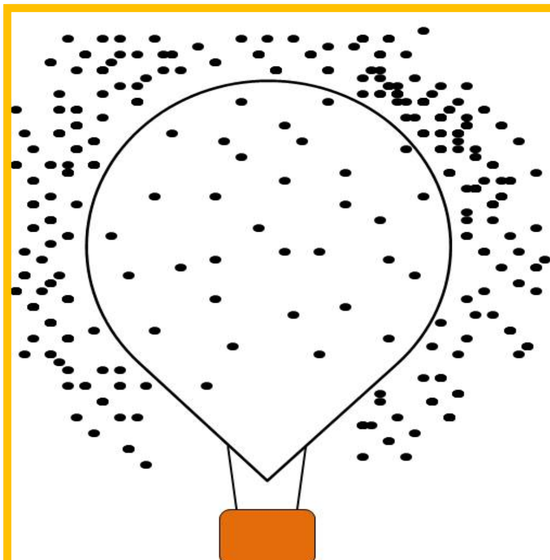
So what about Hot Air

What about hot air balloons? They work by similar principles. If you heat up a gas it expands. In the case of a hot air balloon, when the gas inside the balloon expands the extra gas is pushed out the bottom of the balloon, meaning that there are fewer atoms inside the balloon, meaning that the air in the balloon is lighter than the air outside the balloon.

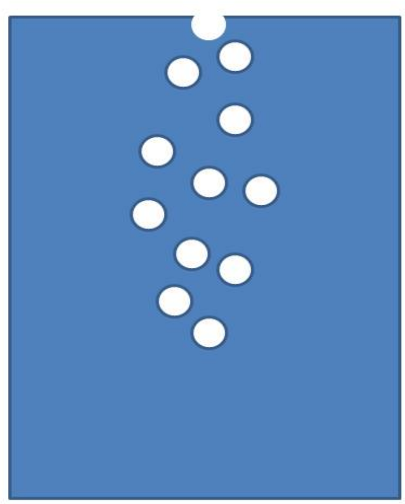
Scientific Sue's Litter Lab

Hot Air Balloon Festival Belfast 2015

The amount of **lifting power** is controlled by how hot the air is. If you heat the air inside the balloon 40 degrees C hotter than the outside air temperature, then the air inside the balloon will be about 25 percent lighter than the air outside the balloon. So 1 L of air weighs about 1.25 grams at 0 degrees C. A 1 L of hot air at 55 degrees C will weigh 25 percent less, or about 0.9 grams. The difference is 0.35 grams or so. So a hot air balloon has to be much bigger to support the same weight, but it will float because hotter air is lighter than cooler air.



The hot air inside the balloon is less dense than the surrounding air, making the balloon rise.



The balloon rises for the same reason bubbles rise in water—they are less dense than their surroundings, and therefore float (that is they are buoyant)!

How did Scientific Sue turn her old helium balloon into a hot air balloon?

Scientific Sue's Litter Lab

A note from Sue:

I hope you enjoyed the show and found these notes helpful. I would appreciate any feedback which would allow the show or the notes to be improved!

If you are interested in finding out about other shows and educational activities on offer please visit my website www.science2life.com

Two new shows have been developed this year and their descriptors are still to be up loaded (aiming for early 2017); they are:

The Science of Dragons Show
The Science of Bubbles Show and

I am also your Network Coordinator for the Institute of Physics – IOP offers FREE teacher training sessions delivered in your own schools. These sessions are for all teachers specialists and non-specialists.

If you have any questions, please don't hesitate in contacting me:

scientificsue@science2life.com

Susan McGrath
BSc Hons. (Physics and Applied Mathematics), PGCE, CEd, DASE, MEd, FInstP
07970884728

The Litter Lab Show has been produced for the

Belfast City Council