InfoChem

STUDENT SUPPLEMENT

ISSUE 124 SEPTEMBER 2010

CLAY PLASTIC FANTASTIC

Nanotechnology is being applied to plastics to make conductive plastics, scratch resistant plastics and lighter plastics. Now clay could make plastics stronger and more flame retardant say Scientists at the State University of New York, US.

Nanoclay

Nanotechnology is the study of science at the nanoscale, between 1–100 nanometres – a nanometre is a billionth of a metre and a human red blood cell is over 2000 nm long. Plastics nanotechnology studies how the addition of nanoparticles – small nanoscale sized particles – to plastic can change the properties of the plastic. The tiny particles can fit between polymer strands and alter how the plastics behave.

Scientists have been studying plastics made with natural clay. The clay nanoparticles can be changed by adding small molecules to their surface and this can change the properties of the plastics in different ways. The new materials can be flame retardant, stronger and more resistant to UV degradation and can be used to make car parts and fuel lines that need to be stable at high temperatures.

Better, cheaper, stronger

To try and improve on current functionalised clays, Miriam Rafailovich and her coworkers in New York added a known flame retardant compound, resourcinol di(phenyl phosphate) (RDP), to natural clay. The new RDP functionalised clay can be mass produced with continuous processing, making manufacture much cheaper. In addition, the new clays generate less dust and are stable at higher temperatures. Rafailovich made plastics with RDP-coated nanoclay particles and showed that plastics made with these nanoclays have superior flame retardance. In addition, RDP clay can be used with styrene plastics, one of the most widely used types of plastic, which has previously been impossible with this technology.

Moulding new materials using clay

THINKSTOCK

Did you know?

Canadians have been feeding pigs seaweed to make omega-3 rich bacon.

Omega-3 fatty acids have known health benefits. Oily fish like salmon are the most available source of omega-3 fatty acids but the fatty acid DHA can also be found in algae. Scientists added 'algal biomass' to pig feed and the bacon's DHA levels increased. Eventually the scientists hope to market their pork. Could a healthier fry-up be on your table soon?

IN THIS ISSUE

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CSI: CHEMICAL SCIEN

ISSUE 124 SEPTEMBER 2010

This is the second in a short series of articles that explores the role of chemical scientists in forensic investigations.
In this issue: Arson or accident?

In 1985, at the Bradford City football ground, white smoke was seen emerging from beneath the terraced seating of the 77 year-old wooden building. Within two minutes the main stand was engulfed in flames. The speed of events was fast and 56 fans were trapped and died while around 200 were injured and others suffered from smoke inhalation. It was concluded that the fire was an accident and not arson. How can you tell the difference?

Arson is a common crime with around 100 000 cases a year in the UK, many of them caused by children and adolescents. The pranks can kill and cause billions of pounds worth of damage.

First glance

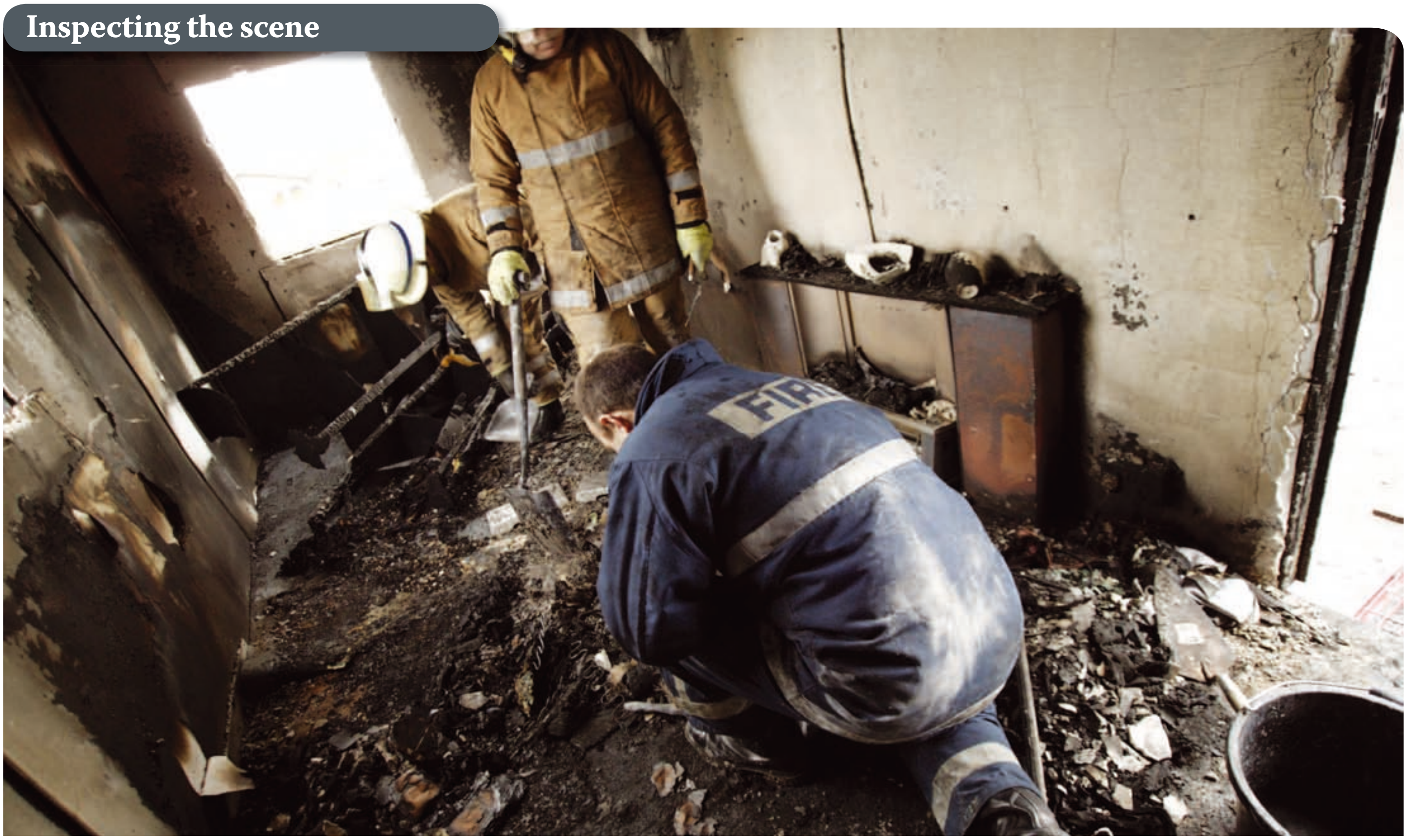
The investigation of fires is one of the most difficult procedures in forensic science because the fire destroys important evidence as it develops and fire fighting can frequently eliminate what few clues remain.

Investigation begins with the experienced eye of the fire-scene investigator who has an extensive knowledge of how materials behave at high temperatures. Establishing the cause of the blaze means finding the seat of the fire. This is done before any laboratory samples are collected. And despite the problems the fire investigation scientist can nearly always come up with the answer to that most important question: how did the fire start?

Chemistry of fire

Fire is a form of rapid oxidation known as combustion. Fire requires a reducing agent, an oxidising agent and thermal energy to start the reaction.

Inspecting the scene



MICHAEL DONNE / SCIENCE PHOTO LIBRARY

TISTS INVESTIGATE

In cases of arson, accelerants – substances used to initiate or promote a fire – are often used. Flammable liquids like petrol or paraffin are common accelerants.

Consider a situation in which an accelerant (*eg* petrol) is absorbed by a rag. The rag is then pushed through the letterbox of a house and then ignited with some burning paper posted through after it. Surrounding materials such as textiles, paintwork and wood heat up and catch fire and a serious blaze ensues.

A typical fire, such as a house fire, involves a variety of fuels, varying amounts of oxygen and a range of temperatures. All this produces some complicated chemistry. Fire chemistry is high-temperature chemistry and this means free-radical chemistry.

Pyrolytic reactions

The main fuel in house fires is wood, which is mainly cellulose as well as small amounts of low molecular mass compounds such as phenols and ketones.

As the wood heats up, usually because of the radiant heat from a flame, a flamable vapour forms around the wood from volatile compounds released from the solid. This glowing hot vapour is the flame. As the temperature increases the cellulose begins to pyrolyse – decompose without oxygen – adding to the flammable vapour and the flames.

In many fires conditions can change rapidly and combustion reactions seldom go to completion – all the fuel being converted to $CO_2 + H_2O$ – because eventually the oxygen level is insufficient to sustain the burning process. Therefore, the atmosphere in a burning building is a complex mixture of volatile compounds.

Forensic analysis

In the initial search after an arson a piece of accelerant soaked rag may be found. While we are tempted to think that all of the petrol would have burnt away, it is often the case that residues – maybe only trace amounts – remain. With a sufficiently sensitive method of analysis these can be analysed.

With samples from a fire scene the forensics laboratory uses gas chromatography (GC) – discussed in the previous article of this series (*InfoChem,* 2010, 123, 2) – coupled to mass spectrometry (GC-MS). In our example the rag from the fire scene is sealed in a plastic bag and rushed to the forensic laboratory. It, or a part of it, is placed into a gas-tight bottle. The bottle is maintained at a certain temperature and vapour is drawn out with a syringe and injected into the GC-MS. The GC part works as described previously but the GC separated molecules go directly to a mass spectrometer.
The spectrometer converts the gas molecules to positive ions by electron loss before a magnetic field then accelerates the ion beam. The ion beam is deflected by the magnetic field by an amount that is proportional to the mass of each particular ion. Similarly, changing the strength of the magnetic field enables ions of a particular mass to be directed to a detector and in this way two main types of information are provided – molecular mass and fragmentation pattern. Using published tables of data, it is possible to identify the molecule passing through the MS as it leaves the GC section.

Evidence?

Conclusion

Examination of a fire scene requires a multidisciplinary approach and chemistry plays

Treated like a crime scene

JIM VARNEY / SCIENCE PHOTO LIBRARY; THINKSTOCK

"FIRE CHEMISTRY IS HIGH TEMPERATURE CHEMISTRY... FREE RADICAL CHEMISTRY"

From such small beginnings...

a major part. Chemistry's role is crucial to identify trace amounts of substances from post-fire debris. Although many fires are not due to arson it is now normal practice to treat each fire scene as if it were a crime scene.

And what of Bradford?

At Bradford the whole event was recorded as the intention was to televise the game – between Bradford City and Lincoln City. This helped the investigation track the path of the fire.

It was concluded that a discarded match or cigarette end had been dropped and fallen beneath the floorboards where there was an accumulation of litter. Bradford City FC had been repeatedly warned about the litter posing a fire risk and had plans to upgrade their stand at the end of the season as they were to be promoted for the next season. In fact, a souvenier edition of the local paper, printed to celebrate the presentation of silverware to the club before the game, detailed the extensive renovation work that was due to take place over the summer.

The Popplewell Inquiry into the Bradford City fire led to legislation to improve the safety at UK football grounds. One result was the banning of new wooden grandstands being built at any UK sports grounds.

Today Bradford still remembers the fire with an annual memorial service on the 11th hour of the 11th day of May, and representatives from Lincoln City always attend.

The Bradford City ground has two memorials to the fire and the team's shirt collars now always have a black trim to remember the 56 people who died in the accident that day. The home end of Lincoln City's ground Sincil Bank is named the Stacy-West stand in honour of Bill Stacey and Jim West, two Lincoln City supportes who were among the dead.

Tony Hargreaves

Case Study

Tony Hargreaves looks at a forensics case study. In this issue: **Greek forest fires**

Proving that an arsonist started a building fire is easier than finding proof that a forest fire was arson. This was the problem faced by the Greek police as forest fires raged from June until September in 2007 and produced a smoke that was clearly visible from space and is recorded on NASA satellite images.

That year, a long dry spell left dead vegetation in a tinder dry condition – all that was needed was a source of ignition. Natural forest fires start due to lightning strikes and the fire produced, in the long term, benefits the health of the forest as it removes dead material and prevents it building up into a much greater fire risk. No doubt some of the Greek fires were due to lightning and some started accidentally or through negligence but, according to the Greek police, many were acts of deliberate fire raising. Altogether the fires destroyed 2700 km^2 of forest and farmland and claimed 84 lives.

Foul play involved?

In July a farmer was arrested on suspicion of causing arson in the Peloponnese area and was given a prison sentence. August saw fire break out near Athens and the police treated it as a case of arson because empty petrol containers were discovered at crucial points. Presumably petrol had been used as an accelerant.

Again in the Peloponnese area, 20 fires were started at the same time making it highly likely that the cause was arson and more suspects were apprehended. In addition to being charged with arson some were also charged with murder. On 27th August a government minister reported that 61 people had been arrested on suspicion of arson.

For arson to occur on such a massive scale calls for a serious look at the motives. One possibility was that many people wanted the forest for land development. This was a contentious issue made worse by the fact that there was no land registry. Previous forest fires had cleared land that was subsequently developed for housing and since the fires of 2007 there has been increased public pressure for the government to enact tougher anti-arson legislation.

THINKSTOCK X2

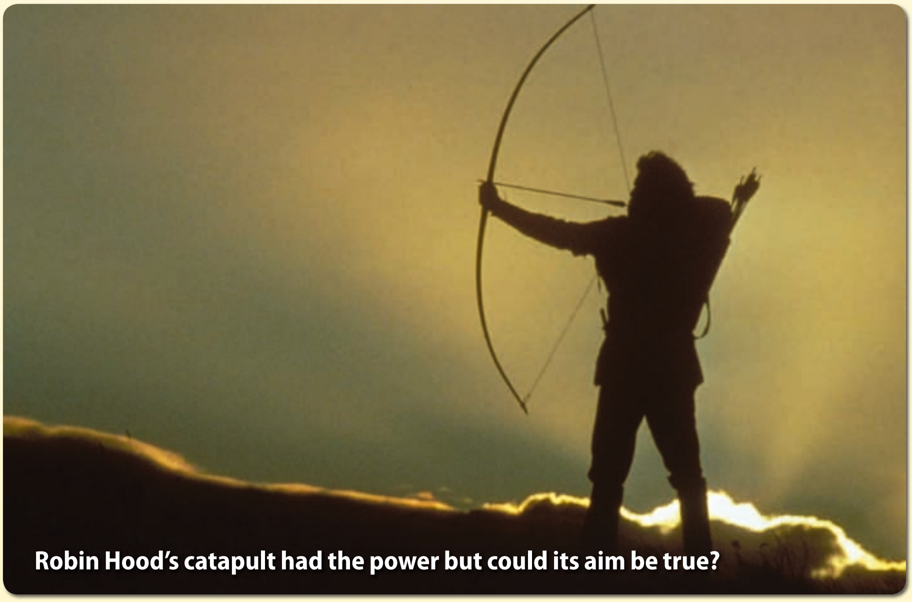
Jonathan Hare asks…

ROBIN HOOD: *a catapult stunt?*

In the 1991version of Robin Hood, starring Kevin Costner,[1] there is a scene where Robin and a friend are catapulted over a castle wall, safely landing onto a large haystack on the other side. It looks great but really how feasible is this stunt?

In the film the catapult looks rather like a giant crossbow with a tensioned string connected to the platform that the two characters sit on. Such a mechanism could develop its power by winding up tension on a rope and unleashing the stored energy like a giant spring.

In antiquity there were catapults and trebuchets capable of flinging heavy objects great distances and there is a legend that the best fibres were made of maidens hair: bundles of long hairs cut from several woman's heads and plated into a rope.



Robin Hood's catapult had the power but could its aim be true?

KOBAL COLLECTION

Hair is composed of keratin – a long stranded protein that twists around other keratin molecules to form rope-like filaments. It is very strong and has a natural elasticity which is good for storing energy.[2] The strength of human hair is far greater than many appreciate and there are circus acts that suspend people from their hair.[3] A typical hair is very fine – about 0.1 mm in diameter – and by hanging weights I found that a typical hair could take 50 g, although hair strength varies from person to person and with ethnicity.[2] To see if a hair could be used we need to estimate the forces on the catapult rope.

If the men in the film each weigh 50 kg – total mass 100 kg – and the walls are 10 m high we get a potential energy $E(\mathrm{p}) = mgh = 100 \times 10 \times 10 = 10\,000$ J. This is equal to the initial kinetic energy needed at lift-off. $E(\mathrm{k}) = \frac{1}{2}mv^2$ gives $10\,000 = \frac{1}{2} \times 100 \times v^2$, so $v = \sqrt{(2 \times 10\,000 / 100)} = \sqrt{200}$ a lift-off velocity of about 14 m s^{-1}.

Let's also say the catapult seat imparts its force over a short period of time *e.g.* $T = 1/4$ s. An estimate of the force would be $F = ma = m$ (change in seat velocity / time) $= 100 \times 14 \times 4 \sim 100 \times 50 = 5000$ N $= 500$ kg *i.e.* about ½ tonne of force. As the catapult is essentially a lever the rope would need to have a much greater force wound up in it, say 10 times the force the seat imparts, the equivalent of *ca.* $10 \times 500 = 5000$ kg $= 5\,000\,000$ g.

If each hair can take 50g we would need $5\,000\,000 / 50 = 100\,000$ hairs – about the number of hairs on a typical head. This amounts to a bundle of about 330×330 hairs in cross section which would only be a few cm in diameter – so not unfeasible. The serious issue is not so much the catapult's ability to lift the load but the accuracy of its trajectory. Even if it could throw them up how would you make sure you didn't smash Robin and his friends onto the walls or simply toss them in the wrong direction – that would be the end of our merry men!

REFERENCES

1. *Robin Hood, Prince of thieves, Warner Bros., 1991.*
2. Hair entry on wikipedia, see: http://en.wikipedia/wiki/Human_hair
3. Hair hang entry on wikipedia, see: http://en.wikipedia/wiki/Hair_hang

Dr Jonathan Hare, The CSC Centre, chemistry department, University of Sussex, Brighton BN1 9ET (www.creative-science.org.uk/TV.html).

Did you know?

Huge mineral wealth has been found in Afghanistan.

American geologists have found nearly $1 trillion worth of mineral deposits, including large lithium reserves. Lithium is a key material for batteries of laptops, mobile phones and mp3 players. This wealth could transform the country.

BACKYARD CHEMISTRY

DR HAL SOSABOWSKI PRESENTS EXPERIMENTS YOU CAN DO ON YOUR OWN

IN THIS ISSUE: hot and cold glowsticks

Kinetics is the science of reaction rates, *ie* how fast a reaction proceeds. The rate of a reaction is determined by several factors, one of which is temperature. As a rough guide, for every 10 degree Celsius rise in temperature, the rate of a reaction will double. This is because as the temperature rises molecules move faster and so collide more often and therefore the number of reactions per second increases.

In this experiment we will demonstrate that heating a reaction increases its rate and cooling a reaction has the opposite effect, because the molecules will move more slowly and so collide less frequently.

Glowsticks are plastic tubes containing glass phials of hydrogen peroxide surrounded by a solution of oxalate ester and fluorescent dye. When the glowstick is bent, the glass phial breaks and the hydrogen peroxide mixes with the oxalate ester, these react producing energy that causes the dye to glow. The rate at which this energy is produced is directly related to the temperature of the glowstick and the faster the rate of reaction, the more energy is produced per second and the brighter the glowstick will glow.

Materials

You will need:

- glowsticks;
- a transparent pudding bowl;
- ice;
- hot tap water.

Method

There are two ways of demonstrating the effect of temperature on the rate of reaction in a glowstick.

Method 1: fill the pudding bowl with ice cubes and add some water and salt – the salt reduces the temperature of the resulting slush. Break and shake a glowstick and place it in the pudding bowl so that half is immersed in the ice slush bath and half isn't. After a few minutes you should notice a difference in the brightness of the lower half compared to the upper half. This is because the rate of the reaction in the cold half of the glowstick is lower because the molecules of hydrogen peroxide and oxalate ester are moving slower and therefore colliding less often than the molecules in the room temperature half.

Method 2: take two identical glowsticks; break and shake them both and place one in the freezer and the other in a bowl of hot water. Leave for 5–10 min then take both glowsticks out and compare their brightness; the glowstick from the freezer will be significantly dimmer than the one from the hot water. Now place the glowstick that had been in the freezer in the hot water for one minute then take it out, shake it, and compare again. The glowstick should glow more brightly now it's hotter since the molecules inside are colliding more frequently.

The science

The brightness of the glowsticks is directly proportional to the temperature – reactions get faster as they get hotter and slower as they get colder. This is why frozen food can be kept for longer because the reactions within the bacteria which would normally cause the food to spoil, are slowed down by the lower temperature.

Health & Safety

There are no particular health and safety issues with this experiment. Do not try to open glowsticks. Take care when using hot tap water.

STEM AMBASSADORS COORDINATOR

Clare Herd

Clare Herd has spent the last 3 months working as the local STEM ambassadors coordinator at Thinktank, Birmingham Science Museum. She talks to Laura Howes about her typical day.

Clare Herd

Science, Technology, Engineering and Maths (STEM) ambassadors are volunteers from a wide range of STEM backgrounds who offer their time and enthusiasm to help schools inspire the next generation of scientists. Clare looks after almost 400 ambassadors in the Birmingham and Solihull area and is in charge of recruiting more volunteers to the scheme.

Stem is important

According to Clare there will be a skills gap in 2014, when it is estimated that employers will be unable to fill around 775 000 positions in their companies that require higher level STEM qualifications. The STEM ambassadors scheme was set up to encourage pupils to study STEM subjects in later stages of education.

Clare's job is to look after the ambassadors already signed up to the scheme and to recruit more. She also pairs up schools and ambassadors to get the best match.

Ambassadors can:

- provide support for activities such as science and engineering clubs;
- help with school competitions, events and awards;
- offer mentoring and careers talks;
- provide work-based placements for teachers and students.

Clare is based at Thinktank, Birmingham Science Museum, and her days can be quite varied. She says that a lot of her job is answering queries and finding out from teachers and schools what they need, 'which is why my own science background is so important', she explains. Clare might spend the morning answering e-mails and phone calls from schools, logging requests for STEM ambassador visits and then matching those requests with the skills of her network of volunteers. In the afternoon Clare might host an induction event for new STEM ambassadors, answering their questions and explaining how the scheme works and discussing the education system and tips on how to be effective.

Clare is always recruiting new ambassadors and often attends events and conferences to meet people who would make good volunteers. Her science background can help her talk to potential volunteers but she believes that her genuine enthusiasm for STEM subjects is even more important. 'I loved studying science and finding out about the world and the scientific approach is a useful skill. It's important for me to be enthusiastic so that I can enthuse others.'

The best bits

Clare isn't a STEM ambassador herself yet, although she says she'd like to be one. She has gone on outreach activities with Thinktank staff, including volunteering at the planetarium and visiting a school induction evening for new starters where she promoted STEM subjects.

Clare finds linking people up the most enjoyable part of her job, finding the right ambassador to visit a school, putting them in touch and knowing what a good job they'll do.

PATHWAY TO SUCCESS

- 2010–present, STEM ambassadors coordinator, ThinkTank, Birmingham
- 2006–2010, PhD in analytical chemistry from the University of Leeds
- 2001–2005, MChem chemistry (1st class) from the University of Leeds
- 2000–2001, student placement, Shell Global Solutions – motorsports team
- 1999–2000, chemistry, biology, physics and general studies A-Levels, Calday Grange Grammar School

PRIZE WORDSEARCH No. 52

Students are invited to find the 29 words/expressions associated with batteries hidden in this grid. Words read in any direction, but are always in a straight line. Some letters may be used more than once. When all the words are found, the unused letters, read in order, will spell a further 10-letter word. Please send your answers to the Editor at the usual address to arrive no later than Tuesday 5 October. First correct answer out of the editor's hat will receive a £20 HMV token.

C	Y	D	C	O	S	E	L	B	I	S	R	E	V	E	R	M
Y	G	I	O	U	E	T	S	O	F	T	W	A	R	E	U	Y
G	O	R	M	V	V	A	R	T	C	E	P	S	L	M	B	R
R	L	E	M	L	I	R	E	E	L	B	I	S	I	V	Y	T
E	O	C	E	I	L	E	M	H	E	A	T	X	S	U	N	S
N	N	T	R	G	F	D	O	O	G	L	A	S	S	E	S	I
E	H	S	C	H	L	A	S	U	P	M	A	L	A	V	U	M
N	C	U	I	T	A	F	I	A	N	A	L	Y	S	I	S	E
O	E	N	A	P	H	T	H	O	P	Y	R	A	N	S	R	H
I	T	L	L	L	N	O	I	T	A	G	U	J	N	O	C	C
T	O	I	D	U	L	T	R	A	V	I	O	L	E	T	E	C
A	N	G	Y	S	P	E	C	T	R	O	S	C	O	P	Y	I
V	A	H	E	R	A	T	E	C	O	N	S	T	A	N	T	N
I	N	T	O	F	A	D	E	K	I	N	E	T	I	C	S	A
T	S	S	E	T	T	E	V	U	C	Z	T	R	A	U	Q	G
C	B	S	E	N	E	Z	N	E	B	L	Y	H	T	E	M	R
A	S	E	S	N	E	L	C	I	M	L	A	H	T	H	P	O

ABSORPTION MAXIMUM
ACTIVATION ENERGY
ANALYSIS
COMMERCIAL DYE
CONJUGATION
DIRECT SUNLIGHT
FADE KINETICS
FADE RATE
GLASSES
HALF LIVES
HEAT
ISOMERS
METHYL BENZENE
NANOTECHNOLOGY
NAPHTHOPYRANS
OPTHALMIC LENSES
ORGANIC CHEMISTRY
QUARTZ CUVETTES
RATE CONSTANT
REVERSIBLE
RUBY
SOFTWARE
SPECTRA
SPECTROSCOPY
SUN
ULTRAVIOLET
UVA LAMP
UV LIGHT
VISIBLE

WORDSEARCH No. 51 winner

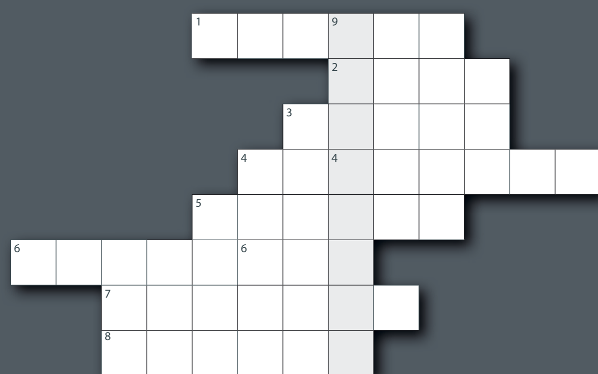
The winner was Jonathan Cooper from Bloxham School, Bloxham, Oxfordshire. The seven-letter word was VOLTAGE.

FIND THE ELEMENT No. 15

Students are invited to solve Benchtalk's *Find the element* puzzle, contributed by Dr Simon Cotton. Your task is to complete the grid by identifying the eight elements using the clues below.

ACROSS

1. Unreactive metal widely used for storage tanks and pipes for hot water.
2. Metal forming compounds once used as (toxic) 'antiknock' petrol additives.
3. Radioactive noble gas.
4. This element forms a gaseous oxide known to form a toxic brown haze over urban expressways.
5. Halogen found in seaweed, including samphire.
6. Forms a colourless oxide that boils at 100°C.
7. This metal forms a carbonate, spread on the ground to counteract acid soil.
8. Alkali metal essential to the functioning of the nervous system; often needs special replacement in very hot weather.



If you have completed this correctly, in 9 down you will have generated the name of a metal which is unreactive and used in electrical circuits; it finds wide use as a catalyst (including exhaust gas converters in cars) and in certain drugs for the chemotherapy of cancers.

Please send you answers to: the Editor, *Education in Chemistry* the Royal Society of Chemistry, Thomas Graham House, Cambridge CB4 0WF, to arrive no later than Tuesday 5 October. First out of the editor's hat to have correctly completed the grid will receive a £30 HMV token.

Find the element no. 14 solutions and winner

The winner was Mihir Parekh, Lawrence Sheriff School, Rugby, Warwickshire.