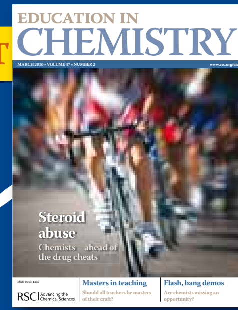
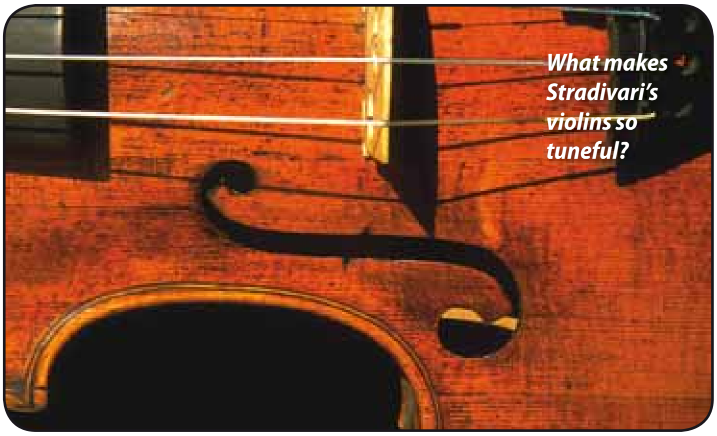
InfoChem
STUDENT SUPPLEMENT



ISSUE 121 MARCH 2010

STRADIVARI KEPT NO SECRETS


What makes Stradivari's violins so tuneful?

The 'legendary' varnish on Stradivari's violins has fascinated musicians and chemists alike for many years. Now, a group of European researchers, having analysed minute samples of the varnish from carefully selected parts of five violins, has found that the master violin-maker used no secret ingredients in the coatings he applied to the instruments.

Jean-Philippe Echard of the Musée de la musique, in Paris, and colleagues elsewhere in France and in Germany, used state-of-the art microscopic and spectroscopic techniques to investigate the varnishes on the Stradivarius violins. Their results confirmed they were composed of nothing more special than the common artists' materials of the day, with cochineal and other red pigments added to give them their particular hue.

The Stradivarius violins examined have been in the collection of the Musée de la musique for at least a century. Although they were produced over a period of three decades, from *ca* 1692, their varnishes are similar. According to Echard, 'Stradivari first applied a layer of an oil comparable to the oils used by painters of the same epoch, without fillers or pigments to seal the wood. We did not find a mineral-rich layer, as some earlier work might have suggested. The master violin-maker next applied a slightly tinted oil-resin layer. We have detected nothing that would have suggested the use of protein-containing materials, gums, or fossil resins'.

'At first, I was surprised by this news', said Tim Lihoreau, creative director of radio station ClassicFM, 'I'd heard that it was something in the varnish that made Strads so special. Having said that, in many ways, the findings only add to the mystique of the Cremonese creator – that in some scientific way, it's a blend of all his crafts coming together to make such legendary instruments'.

David Bradley

Calling all budding science communicators

You could win £100 for yourself and £500 for your school by taking part in this year's Royal Society of Chemistry's (RSC) Bill Bryson prize for science communication.

You can write about any aspect of science that interests you. All formats will be accepted – articles, eg for a magazine or newspaper, posters, poems, PowerPoint presentations, films, information booklets, web pages, or work from an after school science club. Do be accurate in your use of English as well as in the science. And include any experiments that you do. The competition is open to all UK school and college students (aged 5–18) and will be judged in two categories: primary and secondary. The closing date is 21 May. For more details and to download an entry form go to: www.rsc.org/billbrysonprize

ISTOCKPHOTO

IN THIS ISSUE

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THE POISONS OF

ISSUE 121 MARCH 2010

When foreign powers seek to dispose of someone, they look for materials which will escape detection. In recent years poisons – thallium, ricin and polonium-210 – fell into this category.

Politically, assassination by poison can be traced back to ancient times. The Roman empress Agrippina poisoned her husband with arsenic so that she was free to marry her uncle, Emperor Claudius, whom she later poisoned so that her son Nero could take his place.

ARSENIC – ANCIENT KILLER

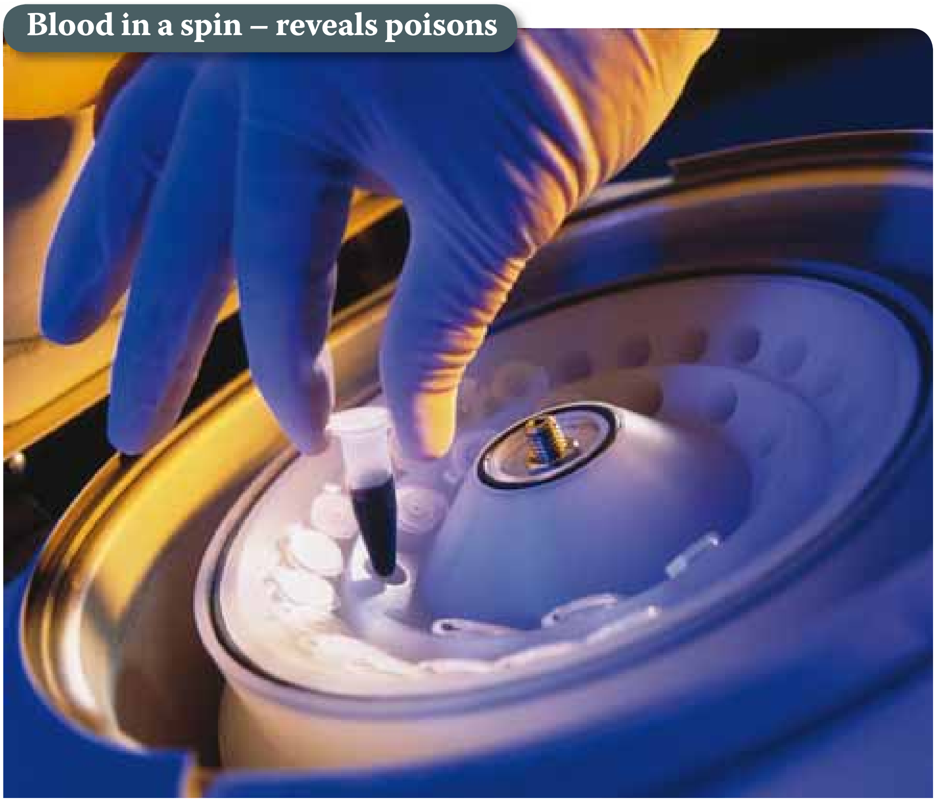
Arsenic(III) oxide [As_2O_3] could be made by heating the yellow mineral pigment, orpiment [As_2S_3]. The oxide dissolves in water to form a colourless, tasteless solution and 250 mg is fatal. In the Middle Ages, folklore suggests that Lucrezia Borgia used it to despatch enemies of her father, Pope Alexander VI.

By the 18th century, the knowledge about poisons increased as did improvements in chemical analysis. Toxicology as a science can trace its roots back to Mathieu Orfila (1787–1853), professor of legal medicine and later of chemistry at the University of Paris. Orfila published the first textbook on toxicology, *A treatise of general toxicology*, in 1813.

In the 1830s James Marsh developed a conclusive test for arsenic, which made it possible to prove that a death had occurred using this agent. The method involved dissolving the suspect sample in strong acid (concentrated HCl), adding zinc to the solution which, if arsenic was present, reacted to form AsH_3 gas (arsine). When arsine was heated in a glass tube it decomposed to elemental arsenic, which was deposited as a shiny mirror.

In more modern times three poisons – thallium, ricin, and polonium-210 – have dominated the armoury of political assassins partly because they are insidious and take several days before they do their worst.

Blood in a spin – reveals poisons



TEK IMAGE/ SCIENCE PHOTO LIBRARY

THALLIUM – THE POISONER'S CHOICE

Thallium as a poison first gained notoriety in the early 1960s when Graham Young, a serial poisoner, used it to poison several of his workmates, some of whom died slow and painful deaths. None of the 30 doctors who attended the victims could identify the cause of their illness until the murderer himself suggested thallium was responsible. Forensic chemists eventually showed that one of his victims, Bob Egle, had been poisoned with thallium by analysing his ashes. While organic poisons would be destroyed by cremation, burning does not destroy metallic atoms such as thallium.

Saddam Hussein's secret agents used thallium(I) sulfate for more than 20 years to murder dissidents at home and abroad. This salt has the added advantage of being soluble, and tasteless. In the 1970s there was no known

SECRET AGENTS

antidote for thallium poisoning, but some of Saddam Hussein's later victims survived when treated with Prussian blue, $KFe(\text{III})[Fe(\text{II})(CN)_6]$, which exchanges potassium for thallium, and carries the latter out of the body.

Ricin poisoning

Ricin is a far deadlier poison and may have been used in the Iran–Iraq war. Ricin comes from the beans of the castor oil plant, and consists of two polypeptide chains, A and B, which are connected by a disulfide bridge (–S–S–). Chain B is the key to the molecule's toxicity. This binds to the outside of a cell membrane and this allows chain A to burrow into the cell itself. Once there it stops the ribosomes that make essential enzymes and the cell dies. A single ricin molecule is sufficient to kill a living cell, so in theory just 3 μg of ricin , with its ten trillion molecules, would be enough to poison every cell in the human body. There still is no antidote for ricin.

The most famous assassination with ricin was that of the Bulgarian dissident author Georgi Markov in September 1978. He was poisoned as he waited for a bus near Waterloo station in London. Someone prodded him with what appeared to be an umbrella but was in fact a disguised airgun, which shot a pin-head sized pellet into his thigh. The pellet had two minute holes drilled into it, both containing ricin, and capable of delivering a fatal dose of ricin. Three days later, Markov was dead.

The pellet was found at autopsy but the two holes were empty. Forensics later proved the poison to be ricin when a similar pellet was extracted from another Bulgarian dissident, Vladimir Kostov who had been attacked on the Paris Metro a few weeks earlier but had survived because most of the ricin was still in the pellet lodged in his back. Today it is relatively easy to prove that ricin has been the cause of death from the antibodies it generates.

It's in the eyes...

Agent 007 – what's his poison?

EPA/CORBIS; JUPITERIMAGES

Polonium-210

In November 2006 43-year-old Alexander Litvinenko, an ex-KGB officer who defected to the west, was murdered in London. He had been given polonium-210 in a cup of tea he drank in the Millennium Hotel in central London. He died three weeks later in University College Hospital.

As little as a microgram of polonium-210 is fatal, and there is no antidote. The element is radioactive and decays by emitting α-rays (helium nuclei). The energy of these particles is enough to destroy living cells. However, since polonium-210 does not emit the tell-tale γ-rays, which can be detected by a Geiger counter, it is relatively easy for it to pass through security checks at airports.

Initially, because Litvinenko's hair started to fall out, the doctors suspected thallium poisoning, but his blood showed little trace of thallium. Hair loss is also a symptom of radiation exposure and tests showed that Litvinenko was passing radioactive urine containing polonium-210. This poison leaves traces everywhere because it is slightly volatile so it was possible to detect it wherever the assassin had been – in aircraft, in hotel

"… AS LITTLE AS A MICROGRAM OF POLONIUM-210 IS FATAL…"

No obvious signs given

bedrooms, in restaurants, and even in the Arsenal football stadium.

Chemical analysis

Forensic toxicologists will generally know, or have been told, which molecules they should test for. When the cause of death is suspicious but unknown they have to do a complex and systematic analysis of a wide variety of samples for possible poisons. The samples most likely to yield the answer are: blood, urine, liver, bile, vitreous humour, cerebrospinal fluid, brain tissue, lungs, hair, and nail clippings.

Samples have to be pre-treated so that the poison can be extracted. In the case of blood this means centrifuging. Since the poison is likely to be present in a tiny amount, solvents such as diethyl ether (ethoxyethane) or chloroform (trichloromethane), which are immiscible in water are used to extract it. The extracted poison is then purified using thin-layer chromatography or high performance liquid chromatography(HPLC). Finally, forensics will identify the chemical by using one or more analytical techniques. Today, by coupling gas chromatography to mass spectrometry (GC–MS) it is possible to identify even the tiniest amounts of a toxin in any organ of the body, including the liquid in the eyeball.

Nowadays it is almost impossible for members of the public to kill someone by poisoning them because poisons are hard to obtain, and those which can be bought will have compounds like Bitrex or dyes added to them to prevent accidental or deliberate misuse. (Bitrex, according to the Guinness Book of Records, is the bitterest substance known.) Moreover, it is almost certain that if someone dies under suspicious circumstances then the cause of death will be discovered such are the skills of today's analytical chemists – unless of course there is a poison we still know nothing about!

John Emsley

FURTHER READING

1. P. C. White (ed), *Crime scene to court*. Cambridge: RSC, 2004.
2. J. Timbrell, *The poison paradox: chemicals as friends and foes*. Oxford: OUP, 2008.
3. John Emsley, *Molecules of murder: criminal molecules and classic cases*. Cambridge: RSC, 2008.

magnificent molecules

Tom Westgate, science writer, highlights his favourite molecules. In this issue: **citric acid**

When you squeeze lemon juice over your pancakes this Shrove Tuesday, you will be using citric acid – 2-hydroxypropane-1,2,3-tricarboxylic acid. This molecule has a host of applications, making it quite a magnificent molecule.

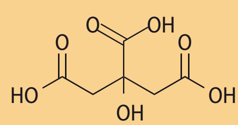
Citric acid gives citrus fruits – oranges, lemons and limes – their bitter taste. The taste receptors on your tongue detect 'sour' when they pick up hydronium ions (H_3O^+), formed when H^+ ions react with water. Citric acid has four available H^+ ions. This bitter taste means citric acid is used as an additive in soft drinks. As well as improving the flavour, citric acid (mixed with its salt, sodium citrate) also acts as a buffer, helping to control the pH. And because it is soluble, this magnificent molecule will even dissolve in concentrated syrups.

Pancakes – with a hint of citric acid

JUPITERIMAGES x 2

Citric acid can also help detergents work better in 'hard' water, which contains minerals such as calcium carbonate and magnesium sulfate. The calcium and magnesium ions bond to the negatively charged ends of detergent molecules, stopping them from forming a lather. Citric acid is sometimes added to detergents because when it loses its H^+ ions, the resulting citrate ion forms a strong bond to these metal ions, letting the detergent molecules get on with their job.

Ever noticed when you add lemon juice to a fruit salad, the apples and bananas don't go brown straight away? The citric acid in the juice makes the pH too low for the enzymes in fruit to react with oxygen, which is the cause of food discolouring.



Citric acid

Jonathan Hare asks…

HOT PARTICLES: *could you blow up the Vatican with antimatter?*

In the film *Angels and demons,*[1] the recent death of the pope has brought together a special meeting of cardinals in Rome. Meanwhile the ancient order of the Illuminati is threatening to blow them up using 'antimatter' recently stolen from CERN's Large Hadron Collider in Geneva. In one scene we see the collider making, isolating and storing the antimatter in what looks like a hand-held battery-powered magnetic vacuum flask. Is this possible, and could you really make a bomb from antimatter?

Exotic particles

CERN accelerates and collides particles at fantastic energies to produce all sorts of exotic particles, including antiparticles. However the lifetimes of these particles are very short: you can't simply bottle the products! You would have to isolate the antimatter because if it came into contact with ordinary matter they would immediately annihilate each other.

In the film the antimatter (probably antihydrogen) would consist of charged nuclei, like a sort of plasma. High-temperature plasmas can be safely isolated within a high vacuum apparatus using strong magnetic fields but this is something that needs a lot of power and complex vacuum systems. So a hand-held device like that shown in the film is not yet plausible.

When a proton (hydrogen) meets an anti-proton (antihydrogen) they annihilate each other, converting their mass into energy by Einstein's equation $E = mc^2$, where c is the speed of light and m is the total mass converted. A small amount of mass can produce a great deal of energy and so given enough antimatter a large explosion could indeed be created.

In the film we hear that the explosive power of the stolen antimatter is '5 k tonnes' (of TNT), about a quarter of the destructive power of the bomb dropped on Hiroshima. How much antimatter are we talking about?

TNT is used as a standard in explosives and is often used to rate nuclear explosions. TNT is defined as producing 4.2×10^9 J tonne^{-1}.[2] If we believe the film we would get a total energy of: $E = 4.2 \times 10^9 \times 5 \times 10^3 = 2.1 \times 10^{13}$ J, and from this we can estimate how much antimatter would be needed in the scene.

If we assume all the antimatter is released and annihilates with ordinary matter, creating energy, we get:

$$m = E/c^2$$
$$= 2.1 \times 10^{13} / (3 \times 10^8)^2$$
$$= 2 \times 10^{-4}\ \text{kg}$$
$$= 0.23\ \text{g}.$$

Since half of this is matter and half antimatter we would have *ca* 0.12 g of antimatter.

Now 1 mole of antihydrogen or hydrogen (1 g) would contain Avogadro's number of particles, so 0.12 g would have about 7×10^{22} 'atoms' of antihydrogen. The volume of the containment flask shown in the film looks a few ml, which at first seems reasonable. However, CERN estimates that their state-of-the-art systems can only contain 10^{12} charged antiparticles;[3] millions and billions of times less than the little hand-held device in the film is supposed to be containing.

The angels are summoned…

SONY PICS/EVERETT/REX FEATURES

In the film all this antimatter was made in the first few seconds of running the large Hadron collider. However, according to CERN they can produce (only) 10^7 antihydrogen per second – at that rate it would take 230 million years to make the antimatter required in the film. So all in all, it's good news for the angels and bad news for the demons.

REFERENCES

1. *Angels and demons*, based on the Dan Brown novel, Columbia Pictures, 2009.
2. For TNT data see: en.wikipedia.org/wike/TNT_equivalent
3. For CERN comments about the film see: public.web.cern.ch/public/en/spotlight/spotlightAandD-en.html

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

Did you know?

Antimatter is a form of matter in which each particle has the opposite set of quantum properties – eg electric charge – to its opposite in the everyday world. So an antielectron, for example, has the same mass as an electron but a positive charge instead of a negative one. The existence of antimatter was predicted by Paul Dirac in the late 1920s. An excellent journey into the world of particle physics is given in John Gribbin's book **Q is for quantum: particle physics from A to Z,** ***published by Phoenix Giant.***

BACKYARD CHEMISTRY

DR HAL SOSABOWSKI PRESENTS EXPERIMENTS YOU CAN DO ON YOUR OWN

IN THIS ISSUE: measuring the speed of light in the kitchen

THE ELECTROMAGNETIC SPECTRUM is the range of all possible frequencies of electromagnetic radiation, and extends from γ-radiation at around 10^{23} Hz, through x-rays (*ca* 10^{19} Hz), ultraviolet light (*ca* 10^{15} Hz), visible light (*ca* 10^{14} Hz), infrared (*ca* 10^{13} Hz), and microwaves (*ca* 10^{9} Hz), to radiowaves (10^{7}). The different types of wave are all related by the equation:

$$\text{velocity } (v) = \text{frequency } (f) \times \text{wavelength } (\lambda)$$

Thus, if we know, or can measure, any two of these quantities, we can calculate the third. In this experiment you will measure the wavelength of microwaves in a microwave oven, and by looking at the specification printed on the back of the oven you will find out the frequency. With these data you can calculate the speed of the microwaves, which is the speed of light.

MATERIALS

You will need:

- four square and uniform slices of bread; a ruler; and margarine.

METHOD

Remove the turntable from the microwave and cover the turning spindle under it with an upturned bowl. Take four square slices of bread and arrange them into a larger square. You may have to cut the crusts off the inner edges where the slices meet to ensure a close fit. Spread a thick layer of margarine all over the bread slices, right up to the edges and put the slices onto the turntable. Place the turntable on the bowl. Cook the bread for 20 s in 5 s bursts, examining the butter in between the bursts. You are looking for melted patches to develop, and different powered microwaves will do this at different rates.

When parallel patches of melted margarine have appeared on two pieces of bread, measure the distance in centimetres between them. Use the centre point of one melted patch to the centre point of the next. Multiply this value by two. This is the wavelength of the microwaves and should be *ca* 12 cm.

Now look at the back of the microwave. There should be a sticker or plate which gives the specification of the oven. You are looking for the 'output frequency'. I measured the wavelength of the microwaves as 11.2 cm (0.112 m) and the frequency of my oven is 2 450 000 000 Hz. Thus, the velocity of the microwaves is:

$= 2\,450\,000\,000 \times 0.12$

$= 274\,000\,000 \text{ m s}^{-1}$

(The literature value is $299\,792\,458 \text{ m s}^{-1}$.)

THE SCIENCE

Microwaves, like light, consist of a series of peaks and troughs. The microwaves bounce from one wall to another. The two waves sometimes cancel each other out, a peak from one will meet a trough from another and the result will be nothing (a cold spot). Sometimes they add together and reinforce each other (a hot spot). This is why microwaves require turntables – to ensures that the food passes through hot spots and is cooked through. The hot spots coincide with the areas where the margarine melts first, and the distance between two of these hot spots is half a complete wavelength.

HEALTH & SAFETY

Inform an adult of the experiment before you try it. If you are competent using a microwave then there are no special safety issues. Do not place anything in the microwave you wouldn't ordinarily place in it, especially metal items. Take care when examining the back of the microwave oven to find out the output frequency, do not attempt to move it without adult help or supervision.

COMMITTEE SPECIALIST
Farrah Bhatti

Farrah Bhatti is a committee specialist on the House of Commons' Energy and Climate Change select committee. She talks to Tom Westgate about her typical day.

Farrah Bhatti

The committee was set up to monitor the policies of the Government's new Department of Energy and Climate Change. It is made up of MPs from all the political parties. The committee runs several inquiries a year. Farrah is currently working on the committee's inquiry into low carbon technologies in a green economy.

Question time
Farrah kicks off an inquiry by writing some key questions, and inviting answers from people or groups she knows will be interested, including members of the public via the web. Once the responses to her questions are in (up to three months later), Farrah goes through these and decides who to invite as 'witnesses' to the inquiry. Every week during an inquiry, the committee holds an evidence session where the members ask witnesses for their opinions on the Government's policy, and at a later stage these committee members will question ministers on the Government policy and put the other witnesses' concerns to them.

In time for each week's session, Farrah prepares a briefing paper to help the committee members put the right questions to the witnesses. The briefing paper will contain the most important facts and figures relating to the session's topics. She also adds some questions for the members to ask the witnesses, if they choose to. A typical session covers 10 topics, and Farrah will prepare a page of information and questions for each one. As committee specialist, it's Farrah's responsibility to ensure that the committee members have the most up-to-date scientific and technical information on topics to be covered. This will help the committee ensure that Government policy is in-line with the latest scientific evidence.

Farrah then takes on her biggest challenge in an inquiry – *ie* writing the official report. For this document, Farrah will study all the evidence from the inquiry's witnesses, pull out important quotations, form arguments for or against current Government policy and, if necessary, make recommendations for how the committee would like the Government to change its policies. Farrah's report will be read first by the committee chairman, and then the rest of the committee, who will make sure they agree with the report's recommendations. It is then sent to the Government's Department of Energy and Climate Change, who have *ca* eight weeks to respond, explaining why they either agree or disagree with the recommendations. They may announce new policies as a result of the report. This process is exciting for Farrah, whose report might have a direct effect on how the Government shapes the future of renewable energy and low-carbon technology in the UK.

Influencing Government policy
For Farrah, the most important part of her job is to be able to translate all the information into summaries that the committee members, who mostly do not have a scientific background, can understand. Hearing a member put one of her questions to an MP, she finds is one of the most satisfying aspects of her job because she feels she has played a part in forming Government policy.

PATHWAY TO SUCCESS

- 2009–present, committee specialist, House of Commons' Energy and Climate Change select committee
- 2008–09, manager, biosciences, Royal Society of Chemistry, London
- 2008, science policy graduate trainee, Royal Society of Chemistry, London
- 2004–08, PhD in organic chemistry at Oriel College, Oxford
- 1999–2004, MSci in chemistry, with a year in industry, at Imperial College, London
- 1997–99, chemistry, biology, maths A-levels, Twyford C of E High School, Acton

PRIZE WORDSEARCH No. 49

Students are invited to find the 29 words/expressions associated with skin cancer 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 nine-letter word. Please send your answers to the Editor at the usual address to arrive no later than Wednesday 7 April. First correct answer out of the editor's hat will receive a £20 HMV token.

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

BASAL CELL
CARCINOMA
CHEMOTHERAPY
DIAGNOSIS
DISEASE
DNA
DNA FINGERPRINT
ENZYMES
EPIDERMAL
IMMUNOTHERAPY
MALIGNANT MELANOMA
MELANIN
MELANOCYTES
MELPHALAN
METASTASISE
MOLE
NON TOXIC PRODRUGS
PIGMENT
PROTEIN
PRIMARY TUMOUR
SECONDARY TUMOURS
SKIN CANCER
SUNBURN
SUN EXPOSURE
SUNLIGHT
TANNING
TISSUE
TYROSINASE ENZYME
ULTRAVIOLET LIGHT

January PRIZE WORDSEARCH No. 48 winner

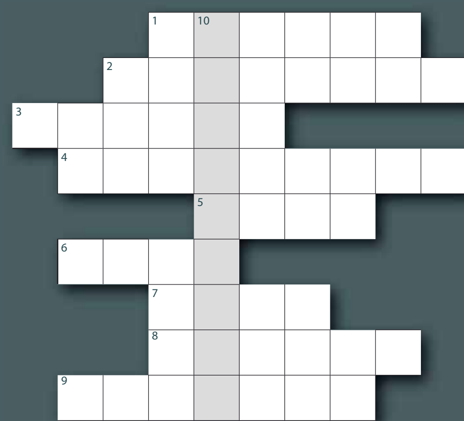
The winner was Emma Bullough from West Sussex.
The 10-letter word was HERBICIDES.

FIND THE ELEMENT

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 10 elements using the clues below.

ACROSS

1. Element used as reducing agent in the blast furnace.
2. Element formed in the oxidation of hydrochloric acid by MnO_2 or $KMnO_4$.
3. Alkali metal slightly more reactive than lithium.
4. Metal that forms thin, tough surface coating of its oxide that prevents further oxidation.
5. Metal that reacts with steam, but not cold water.
6. Gaseous element that does not form molecules.
7. Metal used to corrosion-proof iron by galvanising.
8. Element used to vulcanise rubber to make it hard enough for car tyres.
9. Halogen slightly less reactive than chlorine.



If you have found the correct nine elements, in 10 down you will have generated the name of a metal that reacts with both dilute HCl and NaOH solution, forming hydrogen.

Please send your answers to: the Editor, *Education in Chemistry*, the Royal Society of Chemistry, Burlington House, Piccadilly, London W1J 0BA, to arrive no later than Wednesday 7 April. First out of the editor's hat to have correctly completed the grid will receive a £30 HMV token.

Find the element no. 11 solutions and winner

The winner was Peter. S. Osuoha from Forest Hill School, London.