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China's treasure

REUTERS

A monument in Damao, China. The inscription reads 'The home of rare earths welcomes you'

China has dramatically reduced their exports of rare earth metals in a surprising move for the electronics industry. China has the world's largest reserves of rare earth metals and currently controls almost all the production of them. These metals are used in trillions of dollars worth of high-tech electronics, including smart phones, hybrid cars and wind turbines.

Rare earth metals

Rare earth metals include scandium, yttrium and all the lanthanides. Despite their name, they are not 'rare' in comparison to precious metals like gold or platinum. Rather, because of their geochemical properties, these elements do not concentrate in ores that can be mined easily. Thus, the name 'rare' stems from the expense and difficulty in extracting them from their mineral ores, not necessarily the scarcity of the elements themselves.

Applications

Rare earth metals are used for a variety of applications:

• Neodymium iron boron magnets are the strongest permanent magnets currently known and are used in guided missiles, magnetic resonance imaging and wind turbines.

• Lanthanum nickel hydride batteries are used in hybrid cars because of their high charge densities.

• Erbium-doped fibre amplifiers are used to amplify signals in fibre optic cables, speeding up communication.

• Energy efficient fluorescent lamps, like those in your home, use compounds of Y, La, Ce, Eu, Gd, Tb on the inside surfaces of the bulbs.

Trade

China has the largest of the world's reserves of rare earth metals (37 per cent according to the Royal Geographical Society) with the rest mainly found in Russia, America and Australia. Since discovering these metals in the 1960s, China is now responsible for 97 per cent of the global production. China has gained this near monopoly not just because it has the largest reserves, but also because it offers the lowest prices for these metals.

The unprecedented growth of China's rare earth industry in recent years has led to disorganisation and, taking advantage of this, smuggling has a led to a large proportion of China's resources leaving the country illegally. As China's domestic industries have grown China needs to control its rare earth metal reserves to be able to supply its own industrial demands. This is perhaps why China has made such a major reduction in exports of these valuable metals to the world, reducing them by 72 per cent in the second half of 2010. **Akshat Rathi**

In this issue

▶ **Guest editor Akshat Rathi**

is a DPhil student in organic chemistry at the University of Oxford. He enjoys science writing, photography and following his favourite bands.

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CSI: Under the influence

Beer leads to bangs...

OSCAR BURRIEL / SCIENCE PHOTO LIBRARY

Having alcohol or a psychoactive drug coursing through your veins while driving is foolhardy. It results in impaired judgement and driver errors, which can lead to innocent people being injured and killed.

With greater car usage, and a rise in drunkenness, efforts in the fight against the drunken driver must be relentless. So what role does chemistry play in catching the criminals?

Roadside screening

Introduced in 1967, road-side breath tests used the tube and bag apparatus — later to be known as the breathalyser — to measure a motorist's breath alcohol concentration (BrAC).

A positive result was indicated where the BrAC was greater than 35µg ethanol per 100ml blood. A motorist failing this test would then be required to provide a sample of blood or urine at the police station for further analysis.

Back in 1967, the breathalyser comprised of a glass indicator vial containing yellow crystals of potassium chromate. At the time of the test the police officer would snap off both ends of the vial, leaving a tube of crystals. One end of the tube was then connected to a mouthpiece and the other end was connected to a non-elastic bag that had a capacity of one litre.

The motorist being investigated had to blow through the tube until the bag was fully inflated. If alcohol was present in the breath the crystals changed to green, due to the reduction indicated below. How far the green colouration moved along the tube was proportional to the motorist's breath alcohol concentration.

$$2K_2Cr_2O_7 + 3CH_3CH_2OH + 8H_2SO_4 \rightarrow 2Cr_2(SO_4)_3 + 2K_2SO_4 + 3CH_3COOH + 11H_2O$$

Yellow chromium(VI) → Green chromium(III)

These days the police use an electronic instrument that uses a fuel cell as the alcohol detector; the alcohol is oxidised to acetic acid at the anode generating an electric current. This method offers greater accuracy, and is more reliable and easier to use.

Police station testing

If a roadside test shows a positive indication for alcohol, the motorist is escorted to the police station to take a second breath test. The instrument currently used for police station testing is similar to the infrared spectrometer found in analytical laboratories.

A beam of infrared light is passed through the breath sample contained in a gas cell which is heated to prevent condensation. Parallel to this is a reference cell containing air. Several ethanol absorptions are monitored (C—O, O—H, C—H and C—C bonds) and compensations automatically made for water vapour. A microprocessor ensures that an accurate and reliable result, indicating BrAC, is available in a matter of minutes.

The modern instrument produces a digital readout of the BrAC and will correct for interferences, such as acetone which is found in the breath of a diabetic.

Laboratory analysis

When further testing is called for, a blood sample is sent to the forensic laboratory where headspace gas chromatography (GC) is performed. This method is reliable, accurate and has the advantage of being automated so that many samples can be processed rapidly.

The blood sample, diluted with suitable solvent and containing an internal standard, is placed in a gas-tight vial with a septum and heated in an oven to 60°C so that complete vaporisation of the alcohol occurs. The known amount of internal standard ensures accuracy of results where there are minor variations in the volume of sample injected into the GC.

In headspace analysis, a volume in the gas-tight vial is removed by means of a syringe needle (manual or automated) being pushed through the septum. The vapour is then injected into the GC. The details of the actual GC analysis are as reported in an earlier article (*InfoChem* no. 123, page 2). The quantity of ethanol and internal standard are measured and the result fed to the computer which then reports the blood alcohol concentration.

In addition to the internal standard there are calibration standards comprising different concentrations of ethanol. The rigorous use of standards ensures reliability and precision that is all important in this type of work.

What the results mean

To establish an individual's state of intoxication requires an understanding of how alcohol behaves in the human body, how this behaviour is affected by different circumstances, and how individuals differ.

Obviously the strength of the drink and the volume consumed largely determines how fast intoxication occurs, but there are other factors. Drinking alcohol on a full stomach gives a lower rate of intoxication than drinking on an empty stomach. Also, drinking carbonated alcoholic drinks provides for quicker absorption of alcohol.

The important factor for the police to know is what the BrAC was at the time of an incident and this calls for a back-calculation. In general, the removal of toxins from the blood follows first order kinetics so the rate can be quantified by the half-life. However, large amounts of alcohol behave differently in the body as it saturates the enzyme system involved in its breakdown.

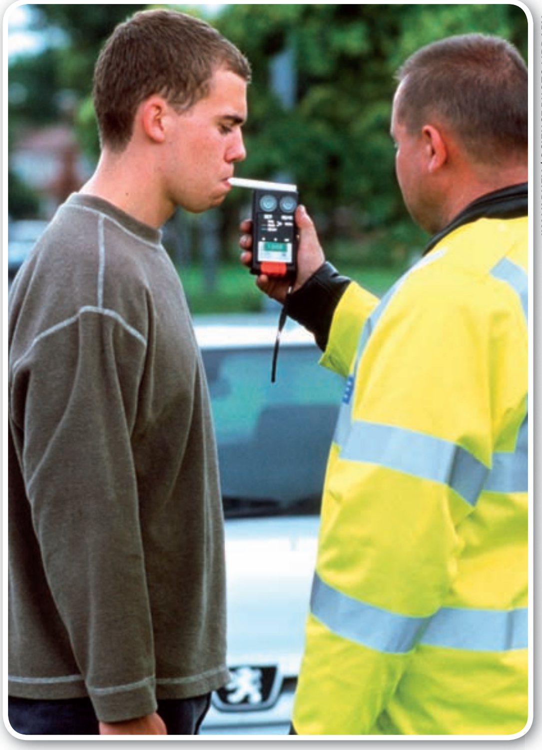
The result is that alcohol in the blood is removed at a constant rate, which allows easy back-calculation of the BrAC. Despite there being a few variables that may influence the rate of elimination a reliable estimate can be arrived at using a simple equation.

Chemical Science Illuminates

Chemistry is at the forefront of the fight against the drunken driver. There are many people alive today thanks to the introduction of roadside screening back in the 1960s. Then, the test was crude and results were not totally reliable but today's testing is reliable and accurate.

Chemists have learnt a great deal about monitoring for alcohol and now some of this knowledge is providing the foundation for testing the motorist for a growing range of other psychoactive drugs that affect a driver's performance.

Tony Hargreaves

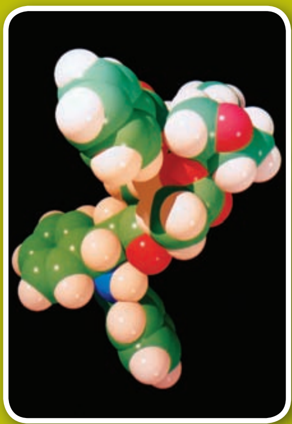


JIM VARNEY / SCIENCE PHOTO LIBRARY

Take a deep breath

GETTY IMAGES

Roadside breath tests were introduce in 1967



NATIONAL CANCER INSTITUTE

Taxol (paclitaxel) was first synthesised by Robert Holton of Florida State University, US, in 1994

Natural product synthesis

Guest editor, Akshat Rathi, on his research at the University of Oxford.

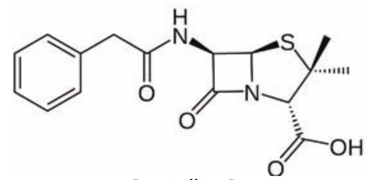
The creation of many new drugs can be attributed to the field that I work in – natural product synthesis. Natural product synthesis is the complete chemical synthesis of the complex organic molecules that exist in nature.

The field began in 1828 when Friedrich Wöhler synthesised urea without any biological means, proving once and for all that living beings were not so distinct from inanimate objects. Wöhler wasn't so pleased though, saying that he had witnessed 'the great tragedy of science, the slaying of a beautiful hypothesis by an ugly fact.' In slaying the idea of 'vitalism', the doctrine that life is not explicable by science, Wöhler is seen as the father of organic chemistry and since then organic chemists have been inventing many ways to achieve their desired results.

One of the greatest discoveries of the 20th century was the discovery of penicillin by Nobel laureate Alexander Fleming. Penicillin, its derivatives, and new antibiotics, are a major contributing factor for the rapid increase in life expectancy in the last century, enabling people to live longer and healthier lives.

However, drug synthesis is only one of the reasons that a chemist might work on natural product synthesis.

Natural product synthesis is used to investigate molecules that have been isolated but never been made before, or to make similar molecules to a previously discovered compound that is known to be a mild drug, so that these analogues can be tested for their activity.



Penicillin G

Complete natural product synthesis can be very difficult to achieve because natural products are often very complicated. However, I find it satisfying to work on because I think it is important for the advancement of knowledge and for the benefit of humankind. The results of natural product research can be used to manufacture drugs, conduct biological studies, develop new methodologies or to simply better understand nature.

Natural product synthesis is many a times referred to as an exact science and a fine art and throughout its history it has attracted some amazingly creative minds, including several Nobel prize winners: E. Fischer (1902), H. Fischer (1930), R.Robinson (1947), R. Woodward (1965), E. Corey (1990). Maybe one of us will be next?

Magnificent molecules

Simon Cotton highlights one of his favourite molecules.

In this issue: (*Z*)-3-hexenal

There are few more evocative smells than freshly-cut grass. If I smell it, I start thinking "cricket season". Topical, with the England cricket team currently in Australia.

When grass is cut, cells are split open. Enzymes break down lipid molecules, releasing unsaturated acids like the C18 molecule linoleic acid. Other enzymes split this into smaller molecules, which are small enough to be detected by their odour. (*Z*)-3-hexenal is the key molecule responsible for the fresh-cut grass smell.

It has an incredibly strong smell but unfortunately, you can't bottle and sell it, because it rapidly converts into more stable molecules, (*E*)-2-hexenal ("leaf aldehyde") and (*Z*)-3-hexen-1-ol ("leaf alcohol"). These have weaker and slightly different green smells. "Leaf alcohol", for example, is used to make perfumes.

There is no doubt that smell taps into our memories and into subconscious emotions. Scientists have studied the effects of green odour on both monkeys and rats, as well as humans, and believe that it has an anti-stress effect.

Plants use these aldehydes as healing compounds, they seal cut ends and stop microorganisms like bacteria from getting to the damaged tissue. (*Z*)-3-hexenal is also a key odorant in fruits like fresh tomatoes and strawberries. Scientists think that the odour of (*Z*)-3-hexenal may be a natural signal from the food, saying "I'm good for you".

And it's not just me that associates (*Z*)-3-hexenal with cricket as well as chemistry. In the 1950s a talented young cricketer named Alan Dixon decided to retire from the sport – as he was not sure of a place in the Kent First XI – and went off to become a travelling salesman.

However, the next spring Alan parked his car next to a cricket ground where they were mowing the grass, and he realised that the smell of that new-mown grass meant so much to him that he rang up the county, asked to come back, and played for another 13 seasons.

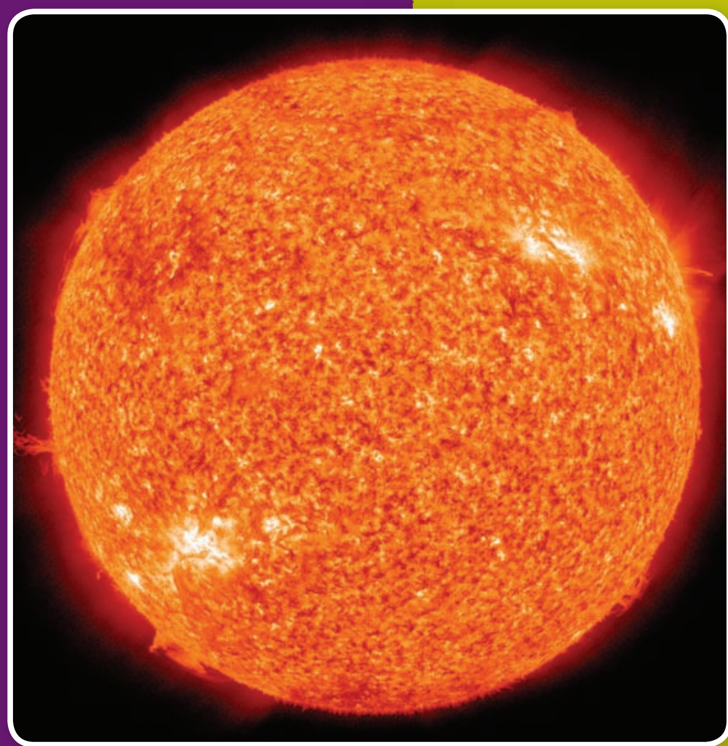
On-screen chemistry

Jonathan Hare explains...

2012 – neutrino chemistry chaos

2012 is a modern, 1970s style classic disaster movie.[1] The movie scenario goes something like this: The energy processes in the Sun are being affected by a very unusual planetary alignment. The alterations to these nuclear processes are causing vast quantities of a new type of particle to be emitted, which on interaction with the Earth's core is heating it up dramatically. This causes the Earth's tectonic plates to start to move rapidly causing vast earthquakes and tidal waves leading to unfolding chaos. In the film we see our heroes in a car (and later in a plane) speeding out of Los Angeles impossibly close to (but always just in front of) vast chasms splitting and swallowing up everything behind them! So how much, if any at all, does this agree with what we know about the science of the Earth and the nuclear chemistry going on in the Sun?

Our Sun is a fairly standard star with core temperatures able to fuse protons in a complex series of reactions known as the p-p cycle. Helium, gamma rays, lots of energy and neutrinos are produced in the fusion process. Neutrinos were first postulated by Wolfgang Pauli and subsequently detected in 1956.[2] Nuclear theory predicts that vast quantities of neutrinos are produced by the Sun but as they have very little mass and no charge their interaction with ordinary matter is tiny. 50 trillion solar neutrinos pass through a human body every second![2]



The sun is a ball of nuclear chemistry

In the 1970s a classic experiment was set-up in a mine in USA by an equally classic experimental scientist, Ray Davis.[2,3,4] Its aim was to detect these illusive neutrinos (ν_e) by their interaction with chlorine to form argon. If the neutrinos have enough energy (ν_e › 814 keV) the following reaction is possible:

$$^{37}_{17}Cl + \nu_e \rightarrow ^{37}_{18}Ar + e^-$$

Using 800 000 pints of cleaning fluid (a cheap source of Cl atoms) and some superb chemistry they were able to detect just *ca.* 12 Ar atoms being produced per month (that's 12 Ar atoms in a tank of around 10^{30} atoms!).[4] This was about a 1/3 of what was expected, causing considerable debate among the theoreticians. One explanation for the 'neutrino number discrepancy' was that neutrinos might come in three types, or 'flavours': electron, muon and tau neutrinos. As the Cl → Ar reaction requires electron neutrinos (ν_e) this explains why the signal was only a 1/3 of the expected value.[3,4]

The film seems to suggest that the planetary alignment is somehow changing the type of neutrinos produced, perhaps to one of the other two types. 'Flavour' oscillations, where the neutrinos change type, have been predicted.[2,3,4] But even if there was some astrophysical mechanism for this there is no reason, given the tiny effect the interactions of these vast quantities of neutrinos have, that there would be any realistic effect on the thermal process going on in the Earth. And certainly not over such a small timescale as the few months, or years of the film.

In summary then: The science is shaky (as if you needed to be told!), so don't bother moving to the Himalayan high ground just yet.

References

1. 2012, Columbia Pictures 2009
2. http://en.wikipedia.org/wiki/Neutrino
3. Project Poltergeist, BBC Horizon TV, 18th March, 2004
4. Neutrino from the Sun, Frontiers in Astronomy, J N Bahcall, Scientific America, 1969

Backyard chemistry

Prof Hal Sosabowski presents experiments you can do on your own

Did you know?

Iron is needed in the body for the correct functioning of a class of enzymes called the cytochromes. Certain foods such as broccoli contain high iron levels.

In this issue: the chemistry of your breakfast

MATTHEW J INGRAM

The food we eat is rarely one 'pure' compound and almost certainly never an element. In this issue's Backyard Chemistry we will examine what makes up two of the constituents of a standard breakfast — cereal and bread.

Many breakfast cereals claim to contain enhanced levels of iron. Iron is important because it is an essential constituent of haemoglobin, the red pigment that carries oxygen in blood. In experiment 1 we will conduct a simple test to indicate the presence of iron in breakfast cereal.

The bread that is also a common constituent of breakfast is mainly comprised of starch. Starch is made of long branched chains of sugar molecules. The chains are broken down by enzymes during digestion, but this happens surprisingly quickly after ingestion. In fact, it happens in the mouth as saliva contains an enzyme which starts the breakdown of starch into simpler sugar molecules that taste sweet.

Milk, the other staple of a good breakfast, can be turned into cheese with a splash of orange juice. The acid in the orange juice causes a hitherto soluble protein to be rendered insoluble. The milk is changed into curds and whey; we have considered the chemistry of milk and cheese in a previous Backyard Chemistry (see *Infochem* no.123 page 6).

Materials:

You will need:
Breakfast cereal which claims to be high in iron;
Two small magnets (neodymium are best);
Inexpensive white sliced bread;
Milk;
Orange juice

Experiment 1

Take a cupful of the cereal and grind it into a fine powder. Add one of the magnets to the dust and stir the dust with the magnet immersed. After a few good stirs retrieve the magnet and observe the grains of cereal sticking to it. You can prove that they are not sticking because of moisture by using the other magnet to remove them; they should jump from one magnet to the other.

The science

Perhaps surprisingly, the form of iron that is added to cereals is elemental iron. Iron is magnetic and the tiny particles of iron react with the hydrochloric acid on the stomach and become soluble Fe^{2+} ions. These cross the small intestine and are then shuttled to where they are required.

Experiment 2

Take a bite of white sliced bread and chew but do not swallow the bread. This will take come self-control. After about five minutes you will notice the bread starts to taste sweeter.

The science

Plants use starch to store sugars which are carbohydrates. These are large chains of sugars which are insoluble in water, whereas the sugars from which they are made are soluble in water. When the starch comes into contact with amylase, the amylase cuts it into molecules of maltose which taste sweet.

Experiment 3

Half fill a glass with full fat milk. Add orange juice to the glass. You will immediately notice small particles forming in the body of the liquid. The taste will also have changed, and it should have slightly cheesy overtones when drunk.

The science

The particles that form when the orange juice is added to the milk are casein, a protein which is soluble at pH 7 (neutral) and exists in milk as the calcium salt. Casein is insoluble below pH 4.6 (acid), and the orange juice – a dilute solution of citric acid – makes the milk acid so that the casein precipitates out, leaving the citric acid as calcium citrate. Casein has a high molecular mass (19 000–24 000 depending on which form) which mean it exists as long chains, a bit like the polymers in plastics.

Health & Safety

There are no particular health & safety issues with this experiment.

A Day in the life of
Oliver Williams

OLIVER WILLIAMS

Research chemist at BP

Oliver Williams has been working as a chemistry at the BP Technology Centre at Pangbourne for nearly two years on their graduate rotation scheme. He talks to Akshat Rathi about his typical day.

British Petroleum (BP), a global oil and gas company, is the third largest energy company in the world. BP's headquarters are in London and in the UK it has research and development sites located at Pangbourne, near Reading, and Hull. Oliver Williams is a graduate chemist based at the site at Pangbourne.

The graduate rotation scheme is designed to give Oliver an exposure and understanding of everything that goes on at the Pangbourne site. As part of the scheme, Oliver previously completed nine months each in Engine Testing and Heavy Duty Diesel Engine Oil Development. He now works in Global Fuels and Lubricants Technology, looking at upcoming fuel and lubricant technologies and how BP can use them in their products.

Research

Currently, Oliver works in the Research and Technology team. The team works on developing better biofuels and fuel additives, and they design experiments so that they can develop recommendations for future fuels – what properties new fuels should have or ideas of what to investigate next.

Designing experiments to investigate new fuels is very complex because there are many uncertain factors, including knowing how the fuel will react. Because of this, Oliver has to gain an in-depth knowledge of the necessary chemical literature in research papers and patents before starting to design his experiments. This is very similar to the research that Oliver did as a student and during his PhD and so he finds the skills and expertise that he gained while studying chemistry for his degree very helpful.

A typical day

Oliver says he does not have a typical day. Sometimes he spends time reading about the latest science. He will also write literature reviews and suggestions for the team. At other times, Oliver plans experiments, which may be run by him or other associates at BP's international research centres. He also has to manage the project that he is involved with, making sure that with so many people involved in it everything is being done by the right people at the right time.

The team Oliver works for is very interdisciplinary with physicists, chemists and engineers all collaborating on the projects. Oliver says that one of the most exciting times of the day is when the team have problem solving meetings and everyone brings a different perspective to the table. As BP often collaborates with researchers based in universities, Oliver is also looking forward to co-supervising a PhD student in the future, although he'll have to wait until he's made a permanent employee first.

Best bits

Oliver enjoys the responsibility that BP has put on him and the freedom he gets working on projects. He is also proud of the work he does because it can potentially have a huge impact. So many people drive cars he says, that small improvements can yield big results.

Pathway to success

2009–present,
joined BP as a chemist on the graduate scheme

2005–2009,
DPhil in organic chemistry at the University of Oxford

2001–2005,
MChem in chemistry with 1st Class Honours at the University of Oxford

1998–2001,
A-levels at Cheltenham College

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£50 of tokens to be won

Benchtalk

Prize wordsearch no. 54

Students are invited to find the 32 words/expressions associated with nanomedicine hidden in this grid, contributed by Bert Neary. 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 7-letter word. Please send your answers to the Editor at the usual address to arrive no later than Thursday 10 February. First correct answer out of the editor's hat will receive a £20 Amazon gift voucher.

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

ANTIVIRAL DRUG
ATOMS
BIOLOGICAL TARGET
CELL
COVALENT BONDS
CHOLESTEROL
DENDRIMERS
DNA
DOUBLE HELIX
ENZYMES
EX VIVO
FIBRES
GELATOR
GENOME
IN SITU
INTERDISCIPLINARY
INTERMOLECULAR
IN VITRO
ION
NANOGELS
NANOSCAFFOLDING
NANOSCALE NETWORK
NERVE CELL
REAGENT
REGROWTH
SPHERICAL
SPINAL CORD
STEM CELL
SUPPORT
SYNTHESIS
SYNTHESISING
TISSUE ENGINEERING

November Prize Wordsearch No. 53 winner

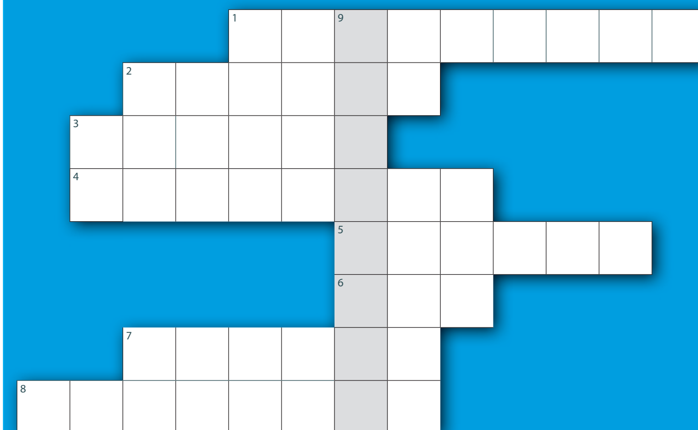
The winner was Mia Pegrum from Barry, Wales. The 8-letter word was PRESSURE.

Find the element No. 17

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

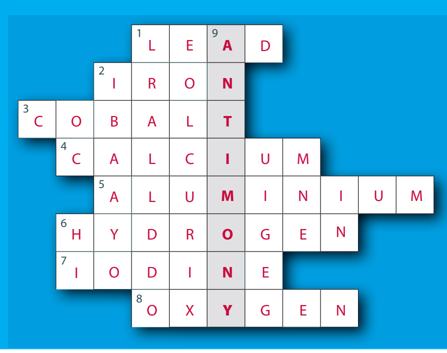
ACROSS

1. All salts of this metal are soluble.
2. Has the lowest boiling point of any gas in the air.
3. Element formed when concentrated sulfuric acid is added to sugar.
4. Molecules of this gas diffuse faster than any other.
5. When you heat the nitrate of this metal, O_2 is the only gas formed.
6. When you alloy this metal with copper, you get bronze.
7. Element formed by catalytic decomposition of hydrogen peroxide.
8. This element strengthens tooth enamel.



If you have completed this correctly, in 9 down you will have the element with the highest melting point of all known metals. It is used to make the filaments of electric light bulbs, and is also used in hard steels for drilling.

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 Thursday 10 February. First out of the editor's hat to have correctly completed the grid will receive a £30 Amazon gift voucher.



Find the element no. 16 solutions and winner

The winner was Moji Ogun Kanmi, St Michael's College, Tenbury Wells.

Name ....

School Name ....

School Address ....

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