The Periodic Table of Sustainable Elements

Date: xx

School: xx

Name:

Student leader booklet

United Nations Educational, Scientific and Cultural Organization

2019 IYPT International Year of the Periodic Table of Chemical Elements

DEAKIN UNIVERSITY

About this event

2019 is the International Year of the Periodic Table of Elements!

To celebrate, we have designed activities to show you some elements that you use in your everyday life. We also want you to see the importance of chemistry in sustainability, because some elements are endangered and we can recycle them rather than throwing them away.

This event is organised by Deakin University, and is financially supported by a 2019 grant from the Australian National Commission for UNESCO grant. We also thank Professor Stuart Batten (Monash University) who designed, sourced and provided the periodic table sets.

This version of the booklet has extra information for students acting as leaders or mentors at the school event. It is not an 'answer' booklet, but it does give some information to help student participants understand a bit more about each of the activities, and to learn about some elements in the periodic table that are considered 'endangered', meaning there is an increasing risk that we will run out of this element in the future.

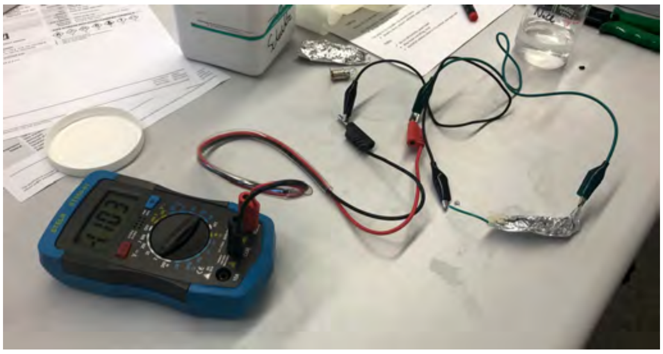
Elements of Sustainable Chemistry

UNESCO
United Nations
Educational, Scientific and
Cultural Organization

Australian
National Commission
for UNESCO

The Periodic Table of Sustainable Elements has received grant funding from the Commonwealth Government through the Australian National Commission for UNESCO

<u>Making an Aluminium - air battery</u>



What is happening?

A battery consists of an anode, a cathode and an electrolyte. In this battery, the anode is the aluminium foil, the cathode is the air in the charcoal, and the electrolyte is the salt water.

When students hook up their battery correctly in the circuit, they will get a reading on their voltmeter. Hook 4 or 5 batteries together in series, one after the other. It should be enough to light up the LED light!

Why does it work?

Aluminium is a very reactive metal. It is so reactive that it can react with oxygen in air! This is why it takes so much energy to refine it from ore in the first place. Once solid aluminium has been made, this energy is stored as chemical potential energy and can be released by reacting with oxygen.

Did you know?

Renewable energy sources such as wind, solar and hydroelectricity require energy to be stored in <u>batteries</u>. Different types of batteries are needed for different purposes; some need to be small and light, others can be heavy and bulky. <u>*Lithium*-ion batteries</u> have a lot of important uses in today's society, but the name is deceptive. They contain a lot more *carbon* (as graphite), *nickel, cobalt, copper* and *aluminium* than they do lithium.

Whilst increased usage of these types of batteries have great potential for society, lithium, nickel and copper are all <u>endangered elements</u>, and so will become limited in supply.

<u>Copper Crystals grown on Aluminium sheet</u>

What is happening?

The agar solution contains copper salts (copper sulfate and copper chloride). In the presence of solid aluminium, the blue copper ions come out of solution to form the brown copper crystals.

It is not a quick reaction, but over time (15-20 minutes) copper branches will start to grow off the sides of the Aluminium sheet.

Why does it work?

Copper is less reactive than aluminium, so the aluminium reacts and turns the copper ions in solution into copper metal. This type of reaction is called a displacement reaction (in this case a copper−aluminum displacement reaction).

The chemical equation for the reaction is $2Al + 3Cu^{2+} \rightarrow 2Al^{3+} + 3Cu$

Did you know?

Copper has excellent conductive properties, requires little maintenance, resists corrosion and is infinitely recyclable. It is used in a lot of electrical applications where you need wires. An exception is overhead power lines which are traditionally made of *aluminium*, as aluminium is lighter and has a higher strength.

Copper was one of the first commonly used metallic elements, in <u>alloys</u> such as brass (mixed with *tin*) and bronze (mixed with *zinc*), in fact bronze was first made over 6000 years ago! Copper was so abundant back then that you could find it in river beds, but is now normally produced from copper ore. Copper is an <u>endangered element</u>, and has limited supply.

<u>Turning Copper coins 'silver' and 'gold'</u>

What is happening?

When the zinc powder is added to the hot sodium hydroxide solution, it forms sodium zincate. When the copper coin is added (1 cent coins were 97% copper), some of the zincate ions gets transferred onto the surface of the copper coin as a layer of zinc, which gives it a shiny silver colour.

When you heat this 'silver' coin, after a few seconds brass is formed, which has a gold colour.

Why does it work?

It will not take place unless the copper and the zinc are in contact. Zinc is more reactive than copper, and so zinc metal dissolves during the reaction. At the same time, the zincate forms a zinc metal coating on the copper coin.

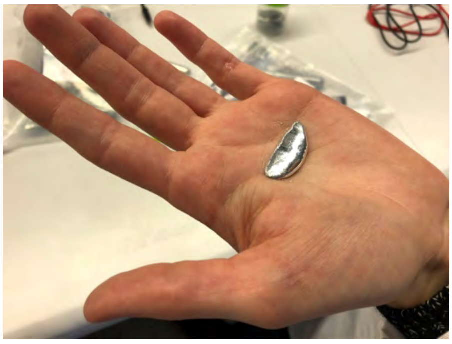
On heating the coin in the Bunsen flame, the zinc and copper atoms at the surface start to mix. Zinc and copper mixed together under heat forms brass, which has a gold colour. Brass is an <u>alloy</u> of copper and zinc.

Did you know?

Zinc is used to protect other materials from corrosion (rust). <u>Galvanised iron</u> is used extensively in Australia for roofing, water tanks and many other purposes. Globally, over 80% of all zinc is used to <u>coat steel structures</u>, to protect them from corrosion.

Despite its relative abundance in the Earth's crust, due to its heavy usage in many industries, it is considered one of our most endangered elements, and we could run out in 20-30 years.

<u>Periodic Table sets and gallium</u>



What do you see and feel with the gallium?

Gallium is a soft, silvery-blue metal that melts at just 30°C – low enough that it can melt in your hands! You might need to warm your hands up a bit by rubbing them together first.

From the Periodic Table set, what can we notice about the elements?

The metals are all shiny solids, though some of them are coloured.

Non-metals are dull and may be coloured. Some metals are much more dense than others; these are lower down on the periodic table.

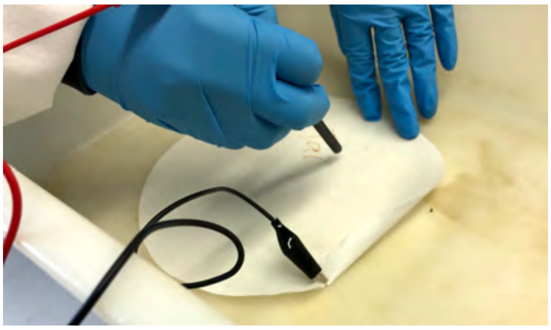
Did you know?

Gallium alloys are used extensively in semiconductors, including in blue LEDs and violet-coloured lasers. The Galinstan alloy is a mixture of gallium, indium and tin, and is a shiny metallic liquid at room temperature that is used in place of mercury in thermometers.

There are <u>so many</u> amazing elements in each box! They don’t look that different, but some of them are <u>very</u> endangered elements. *Tellurium* and *Indium* are essential elements for flat screen TVs and solar panels.

Tantalum is an extremely stable element, and is present in EVERY electronic device. It is found in few places, and two mines in Australia produce more than half of world supply. Illegal mining of coltan (a ‘<u>conflict mineral</u>’ containing Tantalum) fuelled the Second Congo War (‘The Great African War’), the world’s bloodiest war since World War II.

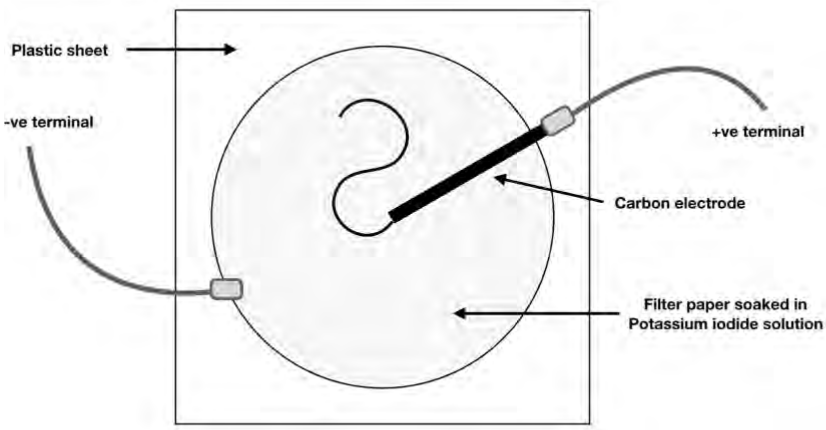
Carbon Rod Writing



What is happening?

The electricity oxidises the iodide ions (with a minus one charge), which are not coloured, to elemental iodine (neutral charge), which is brown.

Why did this happen?



This is an example of electrolysis of potassium iodide (KI) solution. The filter paper soaked in potassium iodide solution forms one electrode of an electric circuit (attached to negative terminal of power source). For the other electrode, a carbon rod (carbon is electrically conductive) is used as a 'pen nib' to 'write' on the filter paper. When this electrode is made positive, the writing (brown iodine) is visible. If you reverse the polarity, the writing disappears.

Did you know?

Iodine is toxic, but is also an essential element for life, as your body uses it in hormones to control growth and metabolism. You therefore require a *very* small amount (130-150 micrograms) in your daily diet. Iodine cannot be made in the body and must be eaten. Most table salt has iodine added to it. There is also iodine in fish and seaweed.

More Iodine experiments

A) Disappearing messages

What is happening?

The message in iodine can be seen because iodine is coloured. The drawing/writings disappears after colouring with ascorbic acid.

Why does it work?

Ascorbic acid gives one of its electrons to each atom of iodine in the solution, which changes it from iodine to colourless iodide.

B) Fingerprinting

What is happening?

Your fingerprint appears on the paper strip a few moments after it is placed in the Schott bottle containing iodine.

Why does it work?

At room temperature, iodine sublimes, as some iodine moves between its solid phase directly to the gas phase.

When your finger is pressed down onto the paper, oils from the skin are transferred to the paper. These oils then react with the iodine vapor, producing a brown color that traces the fingerprint.

DEMONSTRATIONS

Cobalt Pink and Blue

What is happening?

The blue solution we initially see is cobalt (2+) chloride in a solution of pure ethanol. The cobalt (2+) ion appears blue and the ethanol molecules are arranged around it. When water is added, the water weakly binds around the cobalt ions, giving it a different arrangement. This makes the cobalt ion pink.

Did you know?

Cobalt and other metals in the middle of the periodic table are important in biology because they can have different amounts of positive charge, and can make different numbers of chemical bonds. In your body, *iron* is the metal that carries oxygen in your blood from your lungs to your muscles. Cobalt is used to help your body make blood cells. You only have a very small amount of cobalt in your body but without it you would die.

'Traffic Light' and the 'Blue Bottle' reactions

What is happening?

Each bottle contains glucose and a dye in a sodium hydroxide solution. Shaking the bottle causes oxygen in the air to react (oxidise) with the dye.

Indigo carmine: (yellow) + oxygen → (red) + more oxygen → (green)
Methylene blue: (colourless) + oxygen → (blue)

However, when the oxygen runs out, the reaction reverses, and the solutions return to the original colour. Shaking the bottles re-introduces oxygen.

Did you know?

Indigo carmine is used as a food colouring and a pH indicator. Doctors also use it to study kidney and bladder function - they inject the dye into the bloodstream and see how long it takes for the urine to turn green!

The Thermite Reaction

What is happening?

This demonstration shows how two powders can react quite violently with each other, to produce a huge amount of heat. When aluminium reacts with iron (+3) oxide, it is a highly exothermic reaction. Aluminium is more reactive than iron, and so it reacts with form aluminium oxide, leaving iron.

Huge amounts of heat and energy are released during this reaction. The temperature can reach over 2000^{o}C, which is higher than iron's melting point (1535^{o}C).
When the molten iron drops into the water, huge clouds of steam are also rapidly released as the water vaporises.

Did you know?

The thermite reaction, also known as the Goldschmidt process, is used to join train tracks together via an amazing process called exothermic welding, which basically involves sending molten iron into a sand mould.

It is very useful for welders as it does not require charcoal or *carbon* like smelting does, and so leaves a nice relatively pure iron metal. Other metals such as *copper* can also be prepared by a thermite reaction. Even *uranium* has been produced from uranium ore by the thermite process!

The most valuable material in the recycling bin – Aluminium (Al)

Aluminium is used for many purposes in modern society. It is very light (look where it is on the periodic table!), non-toxic, does not easily corrode, and it can easily by shaped and moulded. On its own, it is not strong, but mixed with other metals like copper, magnesium and silicon it is very strong while remaining lightweight, making it perfect for planes and other transport.

It is not an endangered element. 8.1% of the earth's crust is Aluminium! But not only is it used a lot, and it is also very energy intensive to make.

This is because aluminium, like most metals, doesn't exist in pure form. Most metals are found in types of rocks or sediment called ores. Bauxite ore is the world's main source of aluminium and is very common in Australia. Making aluminium from bauxite requires enormous amounts of heat and electricity and has a massive environmental impact.

3% of all of the electrical energy produced in the entire world is used just to produce aluminium. In Victoria, it is even higher. One aluminium smelter (which turns bauxite ore into pure aluminium) in Portland iuses nearly 10% of Victoria's energy supply.

However, aluminium can be recycled easily. Recycling aluminium requires only 5% of the energy that is needed to produce it from bauxite.

Aluminium holds a great amount of chemical potential energy - it is able to make a battery, grow copper crystals, make sparks and even melt iron. Throwing away aluminium cans instead of recycling them is like throwing money in the bin and leaving the lights on for weeks – a huge waste!

Much chemistry research is happening both in Australia and globally, to find ways how industry and the community can use chemicals and elements more sustainably. Chemistry has a central role to play in meeting the 21st century's global sustainable development challenges.

Periodic Table of the Elements

1 H Hydrogen 1.0079																	2 He Helium 4.0026
3 Li Lithium 6.9412	4 Be Beryllium 9.0122											5 B Boron 10.8117	6 C Carbon 12.0108	7 N Nitrogen 14.0067	8 O Oxygen 15.9994	9 F Fluorine 18.9984	10 Ne Neon 20.1898
11 Na Sodium 22.9898	12 Mg Magnesium 24.3051											13 Al Aluminium 26.9815	14 Si Silicon 28.0855	15 P Phosphorus 30.9738	16 S Sulphur 32.0655	17 Cl Chlorine 35.4532	18 Ar Argon 39.9481
19 K Potassium 39.0983	20 Ca Calcium 40.0784	21 Sc Scandium 44.9559	22 Ti Titanium 47.8671	23 V Vanadium 50.9415	24 Cr Chromium 51.9962	25 Mn Manganese 54.938	26 Fe Iron 55.8452	27 Co Cobalt 58.9332	28 Ni Nickel 58.6934	29 Cu Copper 63.5463	30 Zn Zinc 65.4094	31 Ga Gallium 69.7231	32 Ge Germanium 72.641	33 As Arsenic 74.9216	34 Se Selenium 78.963	35 Br Bromine 79.9041	36 Kr Krypton 83.7982
37 Rb Rubidium 85.4678	38 Sr Strontium 87.621	39 Y Yttrium 88.9059	40 Zr Zirconium 91.2242	41 Nb Niobium 92.9064	42 Mo Molybdenum 95.942	43 Tc Technetium (98)	44 Ru Ruthenium 101.072	45 Rh Rhodium 102.9055	46 Pd Palladium 106.421	47 Ag Silver 107.8682	48 Cd Cadmium 112.4118	49 In Indium 114.8183	50 Sn Tin 118.7107	51 Sb Antimony 121.7601	52 Te Tellurium 127.603	53 I Iodine 126.9045	54 Xe Xenon 131.2936
55 Cs Cesium 132.9055	56 Ba Barium 137.3277	71 Lu Lutetium 174.9671	72 Hf Hafnium 178.492	73 Ta Tantalum 180.9479	74 W Tungsten 183.841	75 Re Rhenium 186.2071	76 Os Osmium 190.233	77 Ir Iridium 192.2173	78 Pt Platinum 195.0849	79 Au Gold 196.9666	80 Hg Mercury 200.592	81 Tl Thallium 204.3833	82 Pb Lead 207.21	83 Bi Bismuth 208.9804	84 Po Polonium (208)	85 At Astatine (210)	86 Rn Radon (222)
87 Fr Francium (223)	88 Ra Radium (226)	103 Lr Lawrencium (262)	104 Rf Rutherfordium (261)	105 Db Dubnium (262)	106 Sg Seaborgium (266)	107 Bh Bohrium (264)	108 Hs Hassium (277)	109 Mt Meitnerium (268)	110 Ds Darmstadtium (271)	111 Rg Roentgenium (272)	112 Cn Copernicium (285)	113 Nh Nihonium (284)	114 Fl Flerovium (289)	115 Mc Moscovium (288)	116 Lv Livermorium (293)	117 Ts Tennessine (293)	118 Og Oganesson (294)

57 La Lanthanum 138.9055	58 Ce Cerium 140.1161	59 Pr Praseodymium 140.9077	60 Nd Neodymium 144.2423	61 Pm Promethium (145)	62 Sm Samarium 150.362	63 Eu Europium 152.9641	64 Gd Gadolinium 157.253	65 Tb Terbium 158.9254	66 Dy Dysprosium 162.5001	67 Ho Holmium 164.9303	68 Er Erbium 167.2593	69 Tm Thulium 168.9342	70 Yb Ytterbium 173.043
89 Ac Actinium (227)	90 Th Thorium 232.0381	91 Pa Protactinium 231.0359	92 U Uranium 238.0289	93 Np Neptunium (237)	94 Pu Plutonium (244)	95 Am Americium (243)	96 Cm Curium (247)	97 Bk Berkelium (247)	98 Cf Californium (251).	99 Es Einsteinium (252)	100 Fm Fermium (257)	101 Md Mendelevium (258)	102 No Nobelium (259)