Creating Science – Electroplating

The movement of electrical charges (often thought of as a physics topic) is at the very __heart__ of chemistry. Without it there would be no atomic bonding, and no chemically powered batteries! Today we will use that knowledge to coat a metal object with a thin, and pretty, layer of copper. ***#CreatingScienceElectroplating***

Suggested outcomes

(NOTE: This is by no means an exhaustive list of possible outcomes, neither is it intended that ONLY these outcomes can or should be met. Science is a deeply interrelated activity; all outcomes at all levels, when appropriate, should be integrated.)

Science understanding

- Chemical sciences 1: Everyday materials can be physically changed in a variety of ways.
- Chemical sciences 4: Natural and processed materials have a range of physical properties; these properties can influence their use.
- Chemical sciences 6: Changes to materials can be reversible, such as melting, freezing, evaporating; or irreversible, such as burning and rusting.

Science inquiry skills

- Evaluating 6: Reflect on and suggest improvements to scientific investigations (ACSIS108)

Science as a human endeavour

- Use and influence of science 6: Scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE100)

Cross curricular outcomes

- Visual arts, content outcomes year 5 & 6: Develop and apply techniques and processes when making their artworks (ACAVAM115)

Science vocabulary words

Tier 3 (Specialised vocabulary)

- Electroplating – using electricity to coat one material with another kind of material.
- Electricity – tiny charges of energy that can be used to do work.
- Battery – a device that stores an electric charge.
- Copper Sulphate, aka $CuSO_4$ – a chemical made of copper particles and sulphate particles that are electrically attracted to each other (i.e. they're 'holding hands'). It is used daily in science, for example as a plant fertilizer.
- Ion (high school definition) – a particle with an electric charge. When copper sulphate is mixed with water, the copper and sulphate break apart. The copper has a positive charge of 2, and the sulphate has a negative charge of 2. Thus they are attracted to each other and reform copper sulphate very easily if the water is removed.

Warning

- Copper sulphate is toxic in the wrong amounts. Avoid contact with hands and ESPECIALLY eyes – wear gloves and take all appropriate safety measures. Rinse eyes thoroughly if exposed (though children constantly scratching their eyes is more dangerous than copper sulphate). DISPOSE of your copper sulphate thoughtfully; while dangerous to sea life, copper sulphate is used to treat mineral deficiencies in plants. Pour your used mixtures onto a safe garden area, and NOT down the drain. Wash hands carefully after use.
- Remember: ***Copper sulphate rusts every other metal it touches*** (almost).
- We are using electricity today. This should be safe for your young scientists, especially since you only need two AA batteries to make it all work. But all caution should be used. Wires WILL get hot if a charge is running through them, especially if the battery has failed.

Preparation

- Some metallic copper. You can get some from a gem store, though most wires are made of copper metal which you can display just as easily.
- Electrolysis is a little bit equipment intensive.
    - $CuSO_4$ – "Copper Sulphate", available from the plant section of your local hardware store (usually – best idea is to call ahead).
    - Two AA batteries or equivalent (you need around 3 volts and .1 of an amp).
    - An anode – something made out of metal, such as a nail, though a strip of copper metal is better.
    - A silver coloured coin. This will be our cathode – something to collect the copper on.
    - Wires to connect the battery to both the coin and the nail. You may need alligator clips to achieve this, though any metal clip will do including bullclips or paperclips.
    - Some water, the purer the better.
    - Something disposable and NON CONDUCTIVE (to electricity) to hold the water and copper sulphate solution, such as a plastic plate.
    - Something to clean coins with. Soap and water is a good start, metal cleaner (but **not** polisher) is also advisable. Perhaps the best idea is to literally file off a layer of metal using sand paper or a file. This is the only way to guarantee there are no impurities on the metal preventing the copper from bonding to the coin.
    - Safety gear. While you don't need gloves or lab coats, they won't go astray in preventing copper sulphate stains or itching in sensitive hands. Glasses should be worn, eyes are simply too fragile and irreplaceable.

Disposal

- Copper sulphate solution is a great fertilizer, but deadly to fish. Poor on a garden, NOT down the drain.
- Use reusable and recyclable materials where possible. Your copper coated coin may serve as decoration for years, or you might like to rub the coating of an use coin as normal.

Learning Intent (student friendly)

'We are learning to' (WALT) – use electrolysis to coat some metal with copper.

Success criteria

'What I'm looking for' (WILF)

- safe handling and procedures
- an understanding of the underlying theory,
- some nice, copper-coated, coins

Student learning goals

Help students make a self-monitored learning goal for this lesson.

Evidence of learning

How will you know when the learning goal is achieved? What EVIDENCE do you have that your students have met or exceeded the learning expectations?

- Students will prepare a presentation on electroplating and discuss one way it is used in society. They may also present their electroplated copper coin, and discuss procedures that worked and how they suggest they can make it work better in the future.

Suggestions for other year levels

As always, more material is presented here than can be used by the average class during the average lesson time. However, since the students' questions can and should guide student learning, more material is presented for your convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

This activity is NOT well suited to this age group except as a demonstration. Carefully managed young scientists may be all right, if you can manage the risk.

Middle:

This activity is aimed at this age level.

Teen:

At this age students are ready for more complex explanations, such as discussions of anions, cations, and the electrical charge in all atoms and molecules. Electrolysis has been used for generations to teach such concepts.

Engage

Display the periodic table of the elements and discuss. High school and other groups may enjoy a discussion of the following:

- Each column is known as a *group*, and all the atoms in the same group share similar qualities. (See table in notes section) One of these qualities is 'electron valence', or, in other words, how many 'hands' each atom has that they can use to 'hold' on to other electrons to make up other chemicals.
- How this table came about. Many contributions were made by many chemists and alchemists to create a working description of the elements that were known, until Russian scientist Dmitri Mendeleev had the key insight of creating a table with gaps, which predicted the qualities of as yet undiscovered elements. His predictions are supported, and we attribute the current periodic table to him.

Point to copper on the table of elements, and then display some metallic copper and some copper sulphate solution. Discuss how the same atoms (particles) can be completely different colours even though they are exactly the same thing, but just arranged differently or hanging out with different atomic 'friends'.

- In the copper metal, the atoms of copper are stuck next to each other (high school – because they are held together by their shared sea of electrons). They appear orange.
- While in liquid state, the copper atoms are floating around freely. They appear blue (high school - the copper forms an ion, floating around in a sea of water and sulphate ions).
- ⇨ Demonstrate that copper can be made green, if it is brought to about 1000^{o}C, by spraying copper sulphate on a naked flame, as with the activity #CreatingScienceSimpleSpectrometry

Ask: Knowing that the solution of copper sulphate has copper in it, do you think it will be possible to use the copper to coat a coin? Any ideas how?

- ⇨ Make sure all students write down any questions they may have generated during this phase regarding the topic for today.

Explore

- ⇨ Encourage and validate student explanations of this phenomenon. You may like to ask students to write or draw their explanation personally to avoid embarrassment to students unfamiliar with this material. Remember, "I don't know" is a valid explanation in science – it is the beginning of learning new things!

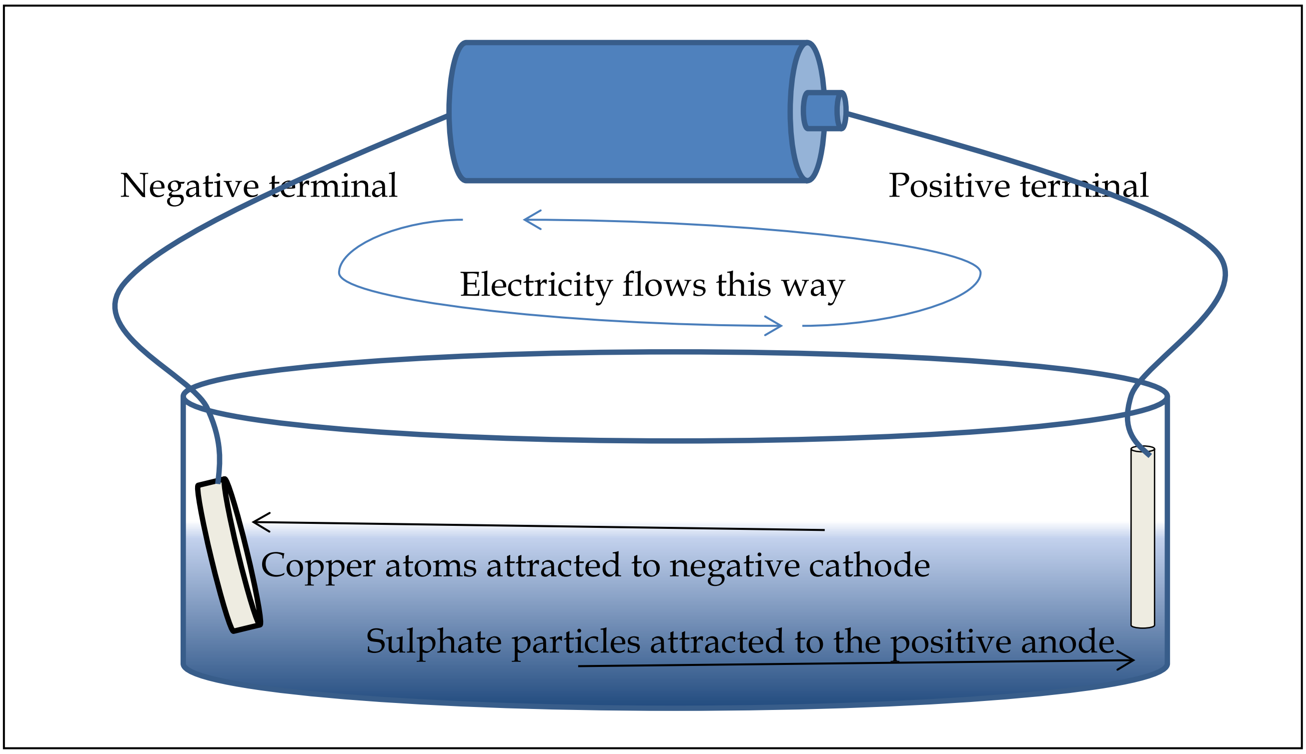
Handle everything with rubber gloves.

- Clean your metal object (coin or key) thoroughly with soap and water and THEN clean it with metal cleaner (but NOT metal polisher, any idea why?) Make sure you dry thoroughly.
- Attach the negative terminal of the battery to the object (in our case, a coin). The area of attachment frequently misses out on being coated. If you can't find a nice, inconspicuous place to attach the battery, you will have to move the point several times during coating. I prefer to coat only half a coin to make the effect obvious and more measurable.
- Set up a solution of copper sulphate in a bowl of water. It should look quite blue, but not have any undissolved copper sulphate chunks lying around (although they won't be a problem, it's just wasteful!)
- Make sure your anode (the nail) is attached to the positive terminal of the battery. Place the anode into copper sulphate solution.
- Lower your metal object into the solution. You may gently swish it around (while being careful not to touch the anode – any ideas why?) The closer the coin is to the anode, the quicker the effect will be. HOWEVER, if the coin is too close the anode, the coin will quickly be covered in a dark black sludge. You can wipe it off and continue. **Patience** is called for, **not** heaps of electricity! Professional electroplating can take *days*.

After about two minutes you should have a nice, thin coating of copper on your metal object. You can polish it, but be careful! The coating is very thin, and it's easy to polish the coating right off. This activity is more for illustration purposes than lasting presentation.

Explain

The chemical solution has positive copper ions that will be attracted to our negatively charged coin when we do our electroplating. Here is a diagram that might help you to picture what is happening:



Elaborate

As soon as you put electricity through the solution of copper sulphate and water, the copper is attracted to the coin and sticks onto it. Meanwhile, the sulphate, which has the opposite electrical charge to the copper, is now attracted to the cathode and sticks to it. The sulphate breaks up, leaving a dark sulphur sludge hanging around that cathode, and allowing the oxygen to bubble up and away. Look carefully, can you see any bubbles?

High school

Copper sulphate in water breaks into two substances, copper ions (with a +2 electric charge) and sulphate ions (with a -2 electric charge). These are attracted to the battery terminal of the opposite electric charge. The copper then coats on to the anode, and the sulphate attaches to the cathode and then loses its oxygen molecules. So you may see the cathode bubbling oxygen, and yes, it can be used to start fires. This is another reason to be careful in chemistry!

(The chemical processes inside batteries sometimes create flammable gasses, such as the hydrogen gas in car batteries. This can, in the right and rarest of conditions, explode. So be careful around batteries and anything that uses electrolysis!)

- ⇨ Explore what else can be safely copper plated. Will anything work? (Caution should be exercised here!)

What do we use electrolysis for in society?

Adapted 16 June 2018 from https://www.quora.com/What-is-electrolysis-used-for-in-everyday-life

- One important use of electrolysis in everyday life is the production of some 'difficult' metals... particularly aluminium, sodium, calcium and magnesium (or the purification of others, such as copper, gold and silver).
- Also the production of chlorine and sodium hydroxide (caustic soda) by the electrolysis of brine (concentrated salt solution).
- Electroplating objects with chromium, nickel, gold or silver is another good example of everyday electrolysis.
- And more frequently these days, the electrolysis of water is used in the production of hydrogen for fuel, or the generation of electricity using fuel cells
- EDIT: Malcolm Sargeant has pointed out in a comment a couple of the most common uses of electrolysis that I overlooked - Rechargeable Batteries and Electrolytic Capacitors. Thanks Malcolm.

See also:

- Electroplating. For example, chromium plating is done on many objects such as car parts, bath taps, kitchen gas burners, wheel rims and many others for the fact that chromium is very corrosion-resistant, and thus prolongs the life of the parts. It is also used in making expensive jewellery, by coating cheaper, silver, jewellery with a thin coat of gold.

- And, of course, it has been used for centuries in art and sculptures. http://www.philamuseum.org/booklets/7_42_73_1.html

Evaluate

⇨ Review with students what they felt they learnt from this lesson. Did they have any questions at the start that they feel were answered?

⇨ Ask students if they can design new ways to test this explanation, is it really sufficient? Can they think of further or better explanations, and the experiments needed to test them?

Guide students in a discussion of how to make their electroplating more effective.

- More electricity **won't help**. Too much and it 'burns', too little and it takes too long. You need to get it just right, and generally, the *longer you give it* the more permanent and thicker the bond.
- Purer chemicals will naturally improve the process, such as using distilled water and scientific grade copper sulphate (around $200 a kilo…)

The best electroplating is not a matter of power or speed, but of patience and quality.

Success criteria

⇨ Review the Learning Intentions of this lesson with students. Was it met?

- o Did they make a copper coated coin?
- o Can they explain the process, and perhaps suggest improvements?

At the end of each class, review the learning objective and see how we did. Ask:

- Did you achieve your learning goal?
- What worked to help you achieve it?
- What might you do better next time?
- (If needed) where can you go for extra help or information?
- What did You learn?

Assessment

Diagnostic:

Seek student opinions on some or all of the following:

- Can atoms join up to make new materials?
- How do atoms connect with each other to form molecules?
- Do you think you can coat one metal with another metal?
- Have you heard about electroplating, what does it mean?

Formative:

Ask students to explain the process of electroplating using the unseen processes of science: the movement of electricity and atomic particles (copper and sulphate) for example.

Ask – what can't be electroplated (generally, insulators)

Help them generate their own understand with some probing questions:

- ⇨ What is in the blue water? [mostly water, but there's copper in there too. When it's dissolved in water it's **blue**, and when it's gathered together as a solid it's **orange**]

Summative:

Help students consider ways they can communicate their new understanding to others, just as scientists need to do.

- Panel a discussion on the electroplating experience and suggestions for improving the process. Allow those willing to experiment further on this activity.
- Research other uses for electroplating. There are many, and they are vital in our society. Share your research with a picture or online video explaining what you have learnt about electroplating.

So what?

- Some chemical changes don't need large amounts of powerful chemicals in order to work the best. They just take the right amount, and plenty of time.
- Some chemicals aren't to be poured down the sink.
- All chemical processes are based on changing electrical charges as atoms exchange electrons in order to bond together. Electrolysis has helped to illustrate this.

Creating science

Science understanding

As we copper plated a coin, we learnt that Everyday materials can be physically changed in a variety of ways (y1), including electrolysis (y6), which can influence their use (y4).

Science inquiry skills

As we thought about ways to improve our copper plating, such as realising it took patience rather than power to work more effectively, we were reflecting on and suggesting improvements to scientific investigations (ACSIS108)

Science as a human endeavour

As we looked into the uses of electroplating in society, such as making metals rust resistant or as used in art, we discovered that scientific knowledge is used to solve problems and inform personal and community decisions (ACSHE100)

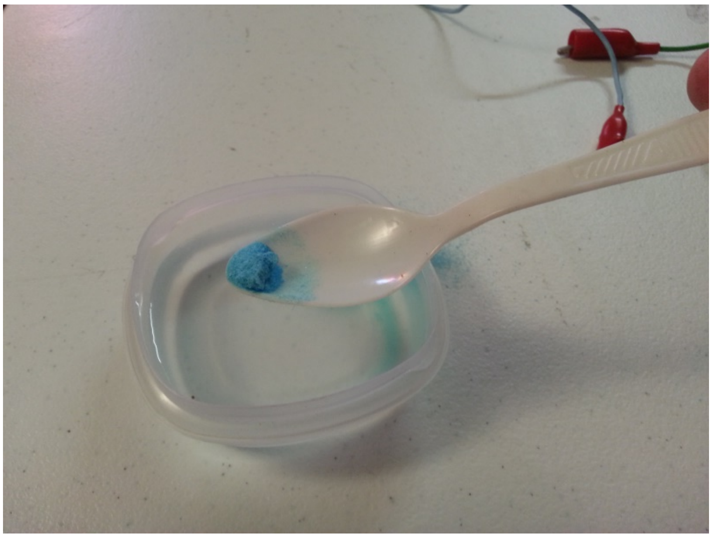
Cross curricular outcomes

Electroplating is a technique used in hundreds of sculptures and paintings.

- Visual arts, content outcomes year 5 & 6: Develop and apply techniques and processes when making their artworks (ACAVAM115)

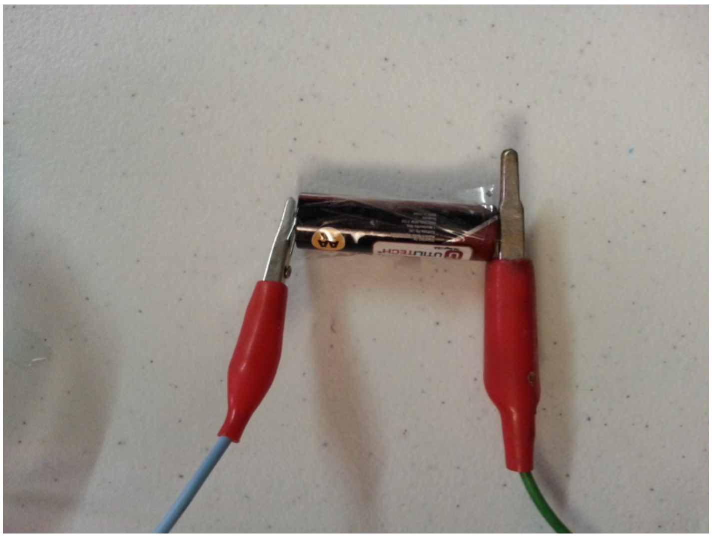
Electroplating pictures

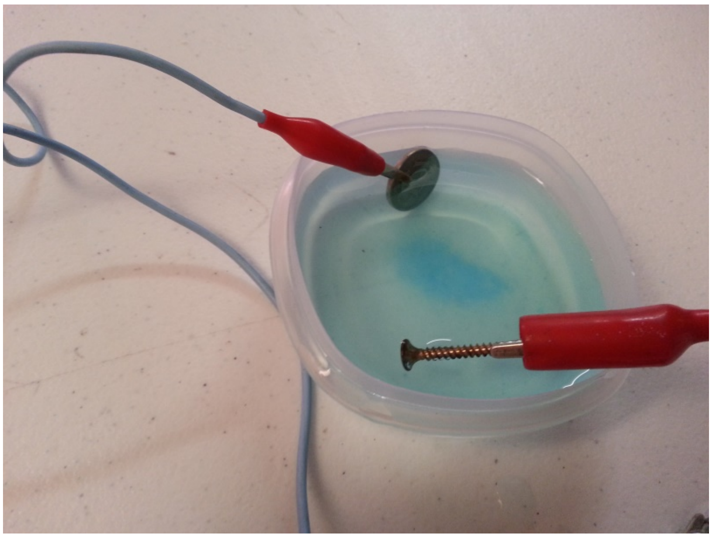
Some gear set up!

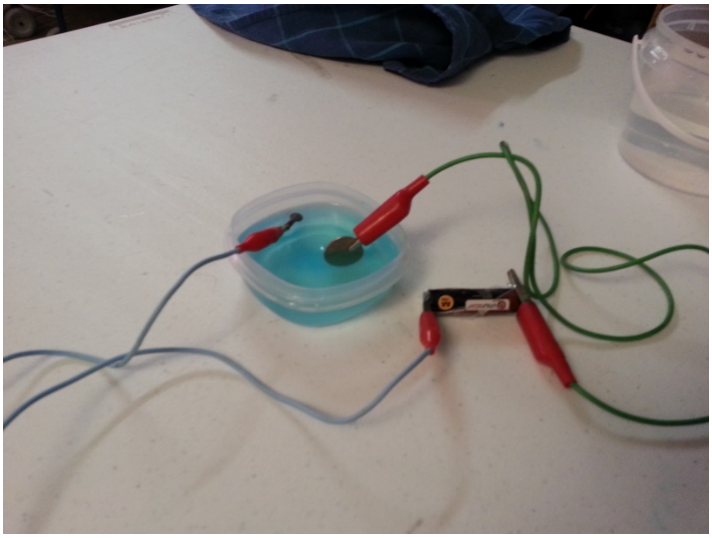


Just a dash of copper sulphate…

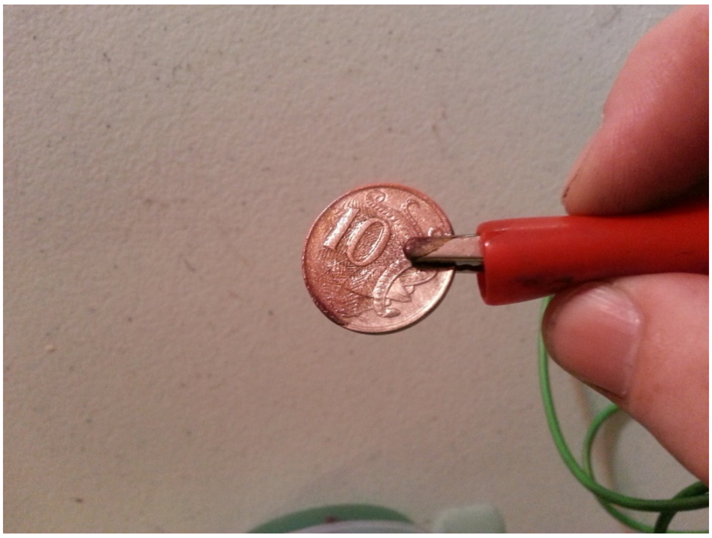
Mix well – no crystals left.


Wires attached securely to the battery.


Coin and cathode waiting patiently.


Get power flowing and wait 10 mins+

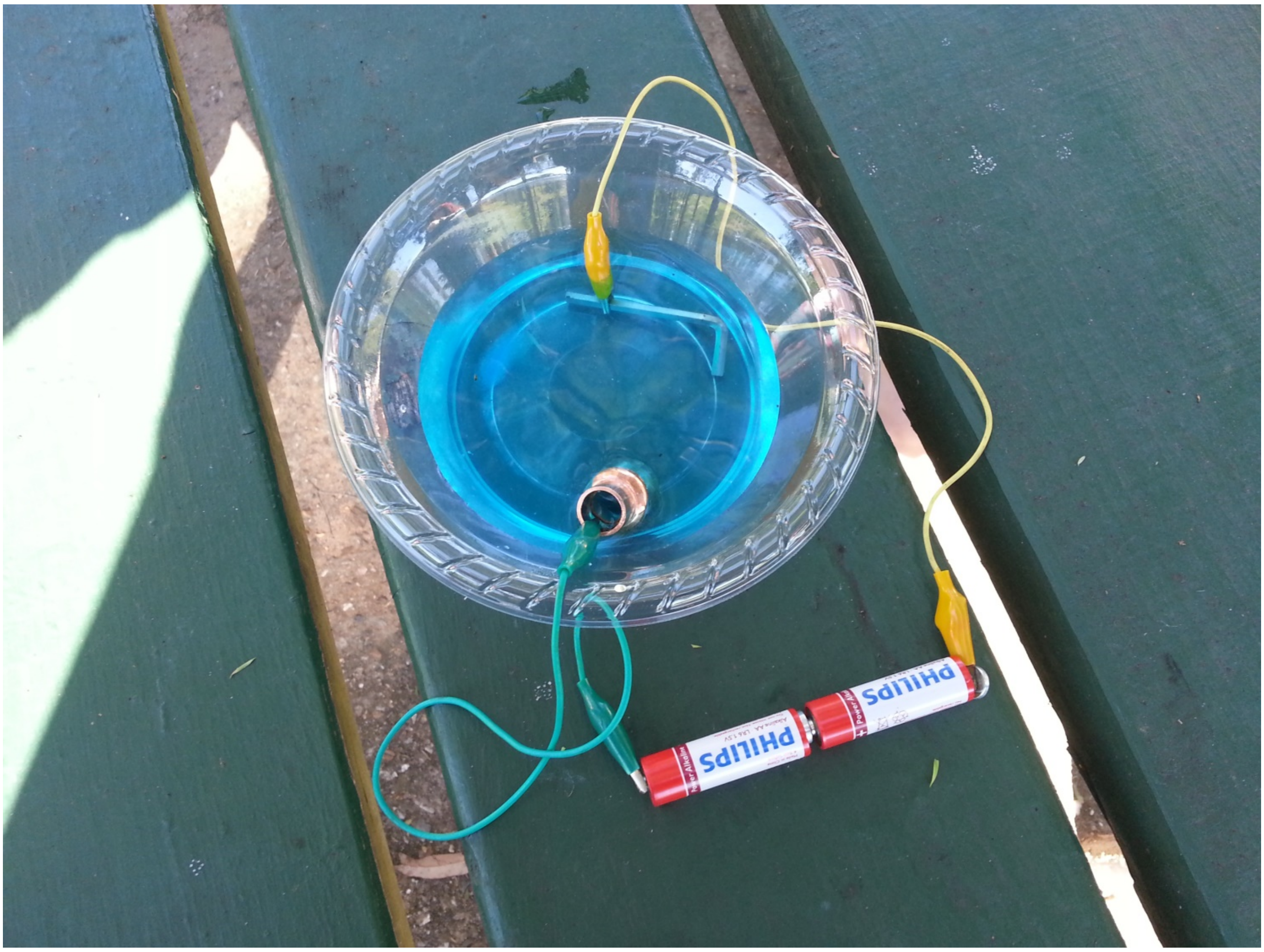
One battery will work, though it will take a lot longer. Two are usually more appropriate.



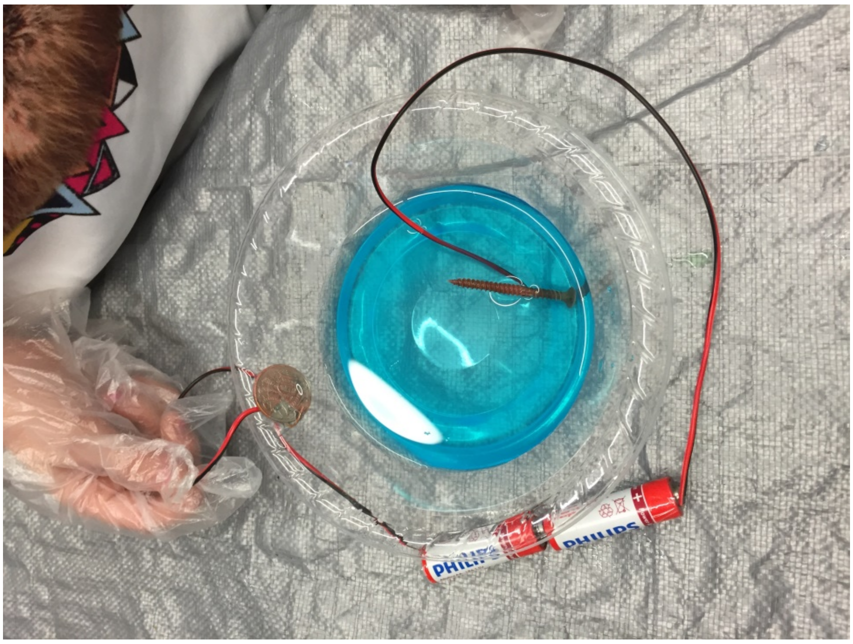
A nice copper coating!

Oops! Someone went too fast; too much electricity or too close.

Unstoppable scientists – two at once! (Note the use of gloves)



Copper plating a hexagonal screwdriver (Neodymium magnets used to hold batteries together and clips onto the batteries.)



The setup is really quite simple!

Name:

Date:

Electroplating learn sheet

Draw your coin after the electroplating treatment.

Draw your theory of how the electricity helped to coat the coin

What suggestions can you make for improving the electroplating process used today?

What other uses are there for electroplating?

Groups in the periodic table																			
Group number[a]	1	2		3[c]	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Trivial name	Alkali metals	Alkaline earth metals										Coinage metals[e]	Volatile metals[e]	Icosagens[e]	Crystallogens[e]	Pnictogens	Chalcogens	Halogens	Noble gases
Name by element	Lithium group	Beryllium group		Scandium group	Titanium group	Vanadium group	Chromium group	Manganese group	Iron group	Cobalt group	Nickel group	Copper group	Zinc group	Boron group	Carbon group	Nitrogen group	Oxygen group	Fluorine group	Helium *or* Neon group
Period 1	H[c]																		He
Period 2	Li	Be												B	C	N	O	F	Ne
Period 3	Na	Mg												Al	Si	P	S	Cl	Ar
Period 4	K	Ca		Sc	Ti	V	Cr	Mn	Fe	Co	Ni	*Cu*	Zn	Ga	Ge	As	Se	Br	Kr
Period 5	Rb	Sr	[d]	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Period 6	Cs	Ba	La–Yb	Lu[d]	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Period 7	Fr	Ra	Ac–No	Lr[d]	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Uut	Fl	Uup	Lv	Uus	Uuo

[a] Current, modern IUPAC group number.
[b] While not included in Mendeleev's original table, Mendeleev later (1902) accepted the evidence for the existence of the noble gases, and placed them in a separate "group 0".
[c] Hydrogen (H), while placed in column 1, is not considered to be in the group alkali metals.
[d] Group 3: depending on the source, lutetium (Lu) and lawrencium (Lr) may be included; lanthanum (La) and actinium (Ac) may be included; the f-block (with 14 lanthanides and 14 actinides) may be included.
[e] This group name is not recommended by IUPAC.

Characteristics

- **Alkali metals** (excluding hydrogen) react explosively with water.
- The **alkaline earth metals** are all shiny, silvery-white, somewhat reactive metals at standard temperature and pressure, and readily lose their two outermost electrons to form cations with charge 2+ and an oxidation state. (As do most other metals that follow after).
- **Nobel gases** hardly react to anything.
- Other groups are known by their tendencies to bond with other items, or the electrovalence. The other groups do not, however, always have similar qualities, making their group as easily distinguished as, say, alkali metals or noble gases.

Table adapted 16 may 2015 from http://en.wikipedia.org/wiki/Group_%28periodic_table%29