

1. MIXING TWO THINGS TO MAKE NEW THINGS

Chemistry can happen when different substances are mixed together, but not always. Mixing is easy to do if the substances are first dissolved to make a solution. If new substances are made that do not dissolve readily, or have a different colour then you can see that a reaction has occurred.

WHAT YOU NEED

Solutions of the following substances (at least 20mL of each) - recipes in Appendix 1
Group A:

- Copper sulphate
- Iron sulphate
- Manganese sulphate
- Calcium chloride

Group B:

- Sodium carbonate
- Sodium hydroxide

Equipment for the experiments:

- Clean test tubes for reactions
- Test tube rack
- Dropper bottles for each solution

WHAT TO DO

1. Put one clean test tube in the rack for each reaction you wish to do.
2. Use a dropper to draw up 2mL of one of the chemical solutions from Group A, and squeeze the liquid into an empty test tube.
3. Use another dropper to put 2mL of a solution from Group B in the same test tube.

4. Gently shake to mix - any reaction should be almost instantaneous.
5. Try different combinations, but you will only see a reaction if you mix one from Group A with one from Group B (and maybe not even then).
6. Completed experiments can be flushed down the sink, with plenty of water.

WHAT IS HAPPENING?

When chemicals dissolve, the particles that they are made of separate. Adding another dissolved chemical means different combinations of particles can be made – sometimes the new products are different colours, or they don't dissolve.

When a particle from one dissolved chemical reacts with a particle from another dissolved chemical to make something which does not dissolve (and so a solid is formed), this new solid is called a **precipitate**. The unused particles stay dissolved (or they might form a different solid precipitate mixed with the first).

Sometimes the new substance formed has a different colour, too, and so you may see a coloured precipitate.



2. SILVER INTO GOLD

Coating objects with a thin layer of metal can give them properties that are useful. Zinc helps stop corrosion, chrome is tough and gold looks appealing. But, chemistry does not always happen automatically; sometimes a source of extra energy is needed.

WHAT YOU NEED

- 200 mL copper sulphate
- 100mm bare copper wire (stripped electrical wire is fine)
- 2x30cm pieces of insulated copper wire, with 2cm stripped ends
- A bright steel nail or 5c coin (clean off any oil or rust)
- 9v battery, best with a battery clip that has two free wires (bare the ends)
- A container of at least 250mL capacity (an empty jar works)
- A couple of clothes pegs or small bulldog clips are helpful

WHAT TO DO

1. Pour the copper sulphate solution into your container.
2. Bend the 100mm piece of bare copper wire into a U-shape, and twist the bare end of one of the pieces of insulated wire tightly onto the centre.
3. Check against the level of the copper sulphate solution, and bend more if you need to so that almost all of the 100mm wire will be under the surface of the liquid when you dangle it in there later.
4. Attach the bare end of the other piece of insulated wire to the metal object (you might need to find a metal clip and twist the wire onto that if you are using a coin).
5. Dangle the target object so that it is completely submerged in the solution (but not lying on the bottom), by bending the insulated wire so it hangs over the edge of the container (this is where the cloths pegs come in handy).
6. Dangle the bent copper wire in the solution too, but make sure it is not touching the object.

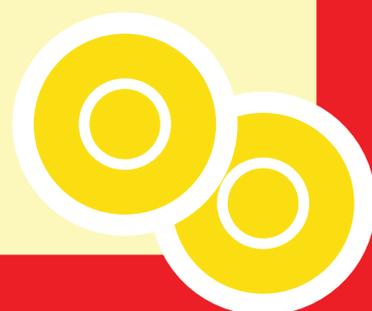
7. The other ends of the insulated wires will connect to the battery: one wire to each terminal. If you have a battery clip, then you can just twist the appropriate wires together. If not, wrapping the bare end of the insulated wire tightly around the battery terminals should work, but you will need to twist tightly to make sure of a good connection (or try holding the bare wire down on the terminal with a small piece of tape).
8. The positive terminal should connect to the bent copper wire, and the negative to the object being coated - you can tell the negative when the experiment is going, because lots of small bubbles will be produced there.
9. Plating takes only a few minutes, but to get an even coating it is a good idea to stir the solution occasionally, and move the object around so different sides are closest to the copper wire.

WHAT IS HAPPENING?

All chemistry involves the electrons that exist around the outside of every type of atom. With the right approach, these electrons can be lured aside on their way to a chemical reaction, and made to do something useful: this is what happens in a battery.

When we use a battery as a pump to push electrons into a piece of metal, the surface of the metal can undergo chemical reactions with passing particles. Passing hydrogen particles from the water are turned into hydrogen gas (hence the bubbling) and if dissolved metal atoms bump into these extra electrons, solid metal is formed.

Because copper metal is a pinkish colour, you can see that a coating has been formed. If a sooty black powder is left on your object, wash or wipe it off and there should be a clean copper metal layer underneath, firmly bonded to the surface.



3. REVERSIBLE COLOUR CHANGES

Flowers, fruits and vegetables can contain natural chemicals which give them their distinct colours. Sometimes, these colours change with time (when fruit ripens, for example) and by doing some simple experiments, you can investigate whether changes are due to some new pigment being made, or if some chemistry might be causing the effect.

WHAT YOU NEED

- A couple of tablespoons of grated beetroot, shredded red cabbage or coloured flowers (reds and purples work best)
- Mortar and pestle for grinding the vegetable material (optional)
- Test tube, or other small, clear reaction container
- 10mL white vinegar (which contains 0.8M acetic acid) with dropper
- 10mL sodium carbonate solution (0.5M) with dropper

WHAT TO DO

1. Grind or mash the coloured vegetable matter of your choice with a few mL of water to extract the coloured juices.
2. Pour the coloured liquid that results into your reaction container (try to avoid the chunky bits).
3. Add the vinegar a drop at a time, stirring between each addition – you should see the colour change, and then stop changing.
4. Now add the sodium carbonate solution – it will take more drops this time, but the colour should first change back to the original, and then change again as you add more.
5. You can keep alternating adding the two solutions, and the colour will keep changing back and forth.

WHAT IS HAPPENING?

White light (including sunlight) is made up of a mixture of all the colours of the rainbow. A pigment looks coloured because it absorbs only some of the colours present in white light and reflects the others (something that looks red absorbs all the blue light, for example, and reflects the red light into our eyes).

The colour of light which is absorbed by a chemical compound (such as a pigment) is determined by the chemical structure of the pigment molecule, and this structure can change slightly depending on how acidic the surrounding environment is. When you add vinegar, you increase the surrounding acidity, and sodium carbonate has the opposite effect (sodium bicarbonate does the same). Chemists measure acidity on the pH scale, and refer to the opposite of an acid as a base (or an alkali, if it is very soluble).

The effect of dilute acids on pigment molecules is usually reversible, which is why you can keep on changing the colour back and forth.

Now you know what colour your pigment is in different environments, you can use it to test other things from around the home – try toothpaste, lemon juice, soda water or kitchen cleaners (it helps if what you test is a liquid, and preferably not coloured). Is there a pattern?



4. WHERE IS THAT SMELL COMING FROM ?

Many artificial scents and flavours as well as natural ones are made up of chemicals that evaporate easily, and react with special receptor molecules in our noses. Artificial scents can be manufactured by reacting two different types of chemical, with the addition of a few drops of acid to make things go faster.

WHAT YOU NEED

- A few mL of an organic acid eg: acetic acid (vinegar) and a dropper
- A few mL of organic alcohol eg: isopropanol (rubbing alcohol) or ethanol (methylated spirits) and a dropper
- Capped plastic vial
- Styrofoam cup (to cut up and make a float)
- Heatproof container (a saucepan works well)
- Hotplate with thermostat (temperature of 50-60°C required)
- A few drops of concentrated hydrochloric acid, and dropper

WHAT TO DO

1. Cut the bottom off a styrofoam cup, or find a flat piece of buoyant material 4-5cm diameter that you can make a hole in easily.
2. Cut a hole in the float big enough to take the plastic reaction vial, and push the vial into the float.
3. Use a dropper to add 1mL of your organic acid to the reaction vial (about 20 drops).
4. Use a clean dropper to add 1mL of the organic alcohol to the same reaction vessel.
5. Using a clean, dry dropper, add a couple of drops of concentrated hydrochloric acid to the reaction vial, close the lid and mix.
6. Fill a saucepan or other heatproof container with water to a depth of 10cm to make a water bath.

7. Place the water bath on your hotplate, and set it to heat to 50-60°C. Do not let the bath boil or the cap will pop on the reaction vial.
8. Put the float with the reaction vial into the water bath so the mixture is surrounded by hot water.
9. Allow the reaction to proceed for 30-60 min, checking to make sure the water level remains enough to keep the reaction vial floating freely (add water if necessary).
10. Carefully remove the reaction vessel from the water bath, and pop open the cap.
11. Hold the vial 5cm from your nose and waft any vapour towards you (try waving over the top of the vial with your hand). A new scent should be obvious, depending on which combination of acid and alcohol you used (see Appendix 2 for examples).
12. Some concentrated acid will remain in the mixture, so dispose of with care (eg: flush down the sink with plenty of water).

WHAT IS HAPPENING?

The acid and alcohol react to make a new compound called an ester, a type of chemical which often has a strong odour. The structure and shape of the ester molecule determines which receptor in your nose it can react with, and so what you smell. Some people have different nose receptors to others, so not everyone can smell the same things. Many natural scents and flavours are esters (see Appendix 2), and these are made in nature using a wide variety of organic acids and alcohols found in living organisms.

This reaction happens very slowly at room temperature (which is why you need to heat it up), and the extra hydrochloric acid also helps make the reaction go faster. The extra acidity from the hydrochloric acid helps start the reaction, but is released again when the reaction is completed (and so it remains in the liquid). Something like this which makes a reaction go faster, but does not get used up is called a catalyst.



5. FIRE AND FOAM

Some chemical reactions produce a gas rather than a solid, and when a few drops of detergent are included in the mix, peculiar foams can result. Different gases can be used to make bubbles that burn, cause a glowing ember to burst into flames, or extinguish the fire that results. Other chemistry can produce gases that stink or poison you (but we won't be investigating them).

WHAT YOU NEED

- Solutions of potassium permanganate and sodium carbonate (10mL each)
- 10mL 5M hydrochloric acid solution (DANGER – read safety advice)
- 10mL hydrogen peroxide solution (6%)
- A few drops of liquid detergent
- 10mL white vinegar
- Test tubes, or other reaction vessels
- Wax taper (or small candle) and matches to light it
- 10-20mm long galvanized nail

WHAT TO DO

To make bubbles of oxygen:

1. Use a clean dropper to put 2mL of potassium permanganate solution into a test tube, and add 1 or 2 drops of liquid detergent.
2. Add 2mL of hydrogen peroxide solution – fizzing should form a foam of bubbles containing oxygen gas.
3. If you light the taper, then blow it out, the glowing ember that results should burst into flame when it touches the oxygen bubbles.
4. If the wet bubbles stop this happening, try again without the detergent, but have the glowing taper ready to insert after you add the hydrogen peroxide – the oxygen formed will be towards the surface of the liquid.

To make bubbles of hydrogen:

1. Gently place a galvanized (zinc coated) nail or screw into a test-tube (don't drop it in, or it might smash through the bottom of the tube).
2. Add 1-2 drops of liquid detergent to the bottom of the tube.
3. Use a clean dropper to add 5mL of 5M hydrochloric acid.
4. The bubbles of hydrogen gas produced are flammable, and will burn and pop when touched gently with a lit taper.
5. If you want to try to capture the hydrogen gas without the detergent, remember it is much lighter than air, and will rapidly float upwards when formed (an inverted container completely covering the mouth of the test tube is required).

To make bubbles of carbon dioxide:

1. Use a clean dropper to add about 2 mL of sodium carbonate solution to a test tube.
2. Add 1-2 drops of liquid detergent.
3. Use another clean dropper to add 2mL vinegar (acetic acid).
4. The bubbles of carbon dioxide produced are not flammable, and will extinguish a flame (this is how some fire extinguishers work).
5. If you want to make a mini-fire extinguisher, instead of using detergent, prepare a delivery tube that can fit into the top of the test tube (this might be a stopper with a hole through it, and some narrow tubing pushed through to direct the flow of gas).
6. Use more reactants to make the gas flow for longer, but keep the same proportions.

WHAT IS HAPPENING?

Each of these reactions produce a gas where there was not one before. The atoms that make up these gases are present in the reacting chemicals, but combined in a way that keeps them from blowing away. As compounds are broken apart and their atoms re-combined during a chemical reaction, some of the new compounds produced can be gases, which form the bubble seen here.

Not all gases have the same chemical properties, and not all of them are lighter than air (which is mainly nitrogen), but all gases have more space between their particles than liquids. This means gases are less dense than the liquid they form in, and so they float to the surface.

Household chemicals can also be used to make chlorine, which is a toxic, choking gas that dissolves in your body to make hydrochloric acid. Not recommended.



6. REVEALING RAINBOWS

Using liquid paints allows you to create a wide variety of hues, simply by mixing different colours together: yellow and blue to make green, for example. Manufacturers use the same technique to produce the variety of colours found in a packet of felt pens, with the darkest colours (browns and blacks) usually having the most ingredients. A simple technique can be used to separate the different coloured chemicals present based on how soluble they are.

WHAT YOU NEED

- Different coloured felt pens (black and darker colours are best)
- Bamboo skewer and sticky tape
- Absorbent paper (coffee filters work fine, but most printer papers are coated)
- A plastic container deep enough that the filter paper hanging from the skewer almost touches the bottom, and narrow enough that the skewer can bridge the top
- Methylated spirits, vinegar and water to make the solvent mixture (quantities will depend on the size of your container)

WHAT TO DO

1. Cut the longest strip you can from the absorbent paper, about 5cm wide.
2. Use different coloured felt pens to make separate dots or lines about 2cm from the bottom of the strip of paper.
3. Fold the top of the strip over the skewer, and attach it in place with a piece of sticky tape.
4. Hang the strip down into the container by balancing the skewer across the top.
5. Prepare enough solvent mixture to fill the container up to the bottom of the paper strip (the liquid must not cover the coloured ink samples, or the ink will simply wash away).
6. The solvent is a mixture of water : methylated spirits : vinegar in the ratio 1:2:2 by volume. Different ratios can be used to change the results.
7. Remove the paper and skewer, and then add the solvent to the container.
8. Replace the paper and skewer, making sure the liquid does not cover the samples of coloured ink. As capillary action draws the solvent up the paper, it will carry the coloured inks along with it but each colour will move at a different rate.

9. When the solvent has moved up far enough to separate the colours, remove the paper from the container, and put it aside to dry.

WHAT IS HAPPENING?

The coloured chemicals in inks stick to paper through weak chemical bonds. The solvent molecules interfere with these bonds, and the coloured chemicals become dissolved in the moving liquid. As they move along with the solvent, the inks continue to make and break bonds with the surface of the paper, which slows down their progress. Because different chemical compounds make bonds of different number and strength, each coloured compound will move at a different speed, and will separate over time, just like runners in a race.

The chemicals used to make the solvent play an important role in this process because their different properties determine how soluble each ink is, and so how fast it moves. This is why changing the ratios, or using different solvents (acetone is another common ingredient) will change the final pattern you see. Similar methods are used in forensic analysis to identify inks and dyes by their individual components.



7. HOW MANY LEMONS DOES IT TAKE TO LIGHT AN LED ?

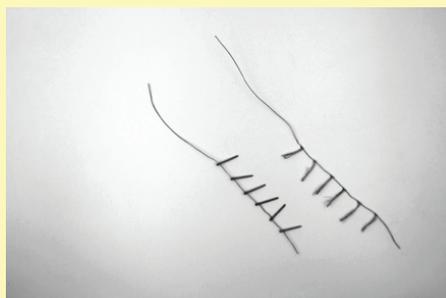
A lemon battery is made by pushing pieces of two different metals into a juicy lemon, and connecting them with a wire – electricity will now flow through the wire. The lemon in this experiment provides a liquid containing dissolved particles that carry positive or negative electrical charges, and their movement is what completes the electrical circuit. In this experiment, we will use a salty solution instead, to save lemons.

WHAT YOU NEED

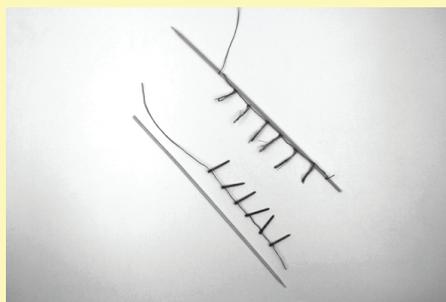
- 6 pieces of braided copper wire about 7.5 cm long, with the insulation removed
- 6 galvanized (or zinc plated) nails, about 2 – 3 cm long
- 2 pieces of copper wire about 30 cm long, with the insulation removed
- 2 pieces of copper wire about 30 cm long, one red and one black, with about 3cm bared at each end
- 2 bamboo skewers
- A shallow container almost as long as the skewers (at least 15cm)
- Solution of 0.2M sodium chloride (enough to fill the container to about 1cm from the top)
- Joule Thief circuit kit (with LED)

WHAT TO DO

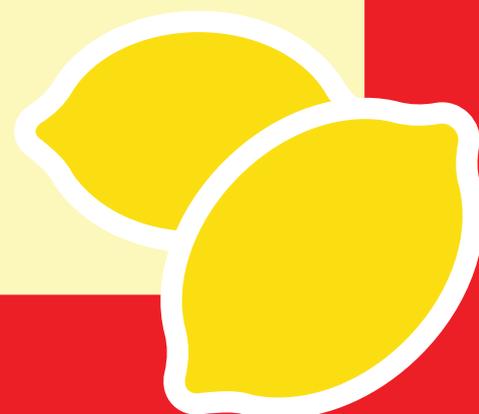
1. Starting about 5cm from one end, attach the 6 galvanized nails along one of the 30cm pieces of copper wire about 2cm apart by looping and twisting the wire tightly around their heads.
2. Similarly, start about 5cm from one end of another 30cm piece of copper wire, and attach the 6 pieces of braided copper wire along the wire about 2cm apart by looping the braided piece over the wire, and twisting tightly to hold it in place. Bend the free ends down so they all hang in a row, like the nails. See picture below:



3. Fix the wire and attached nails to one of the skewers by twisting the short end of the supporting wire around it. Twist on the longer end, too, but leave several cm free for later use:



4. Fix the other wire with the braided copper electrodes to the second skewer using the free ends as before.
5. Balance the skewers across the container. Make sure that the nails do not touch each other, or the braided wires.
6. Follow the instructions located on The Edge website: www.edgeqld.org.au/joule-thief to construct the Joule Thief circuit, attaching the 30cm pieces of insulated copper wire where the red and black motor wires are indicated respectively.
7. One end of the wire with the nails attached should be standing free from the straw. Twist together with the black wire from the Joule thief.
8. Twist the free end of the red wire to the wire on the other straw with the dangling braided copper wires attached.
9. Check again that the nails and braided wires are not touching each other, and pour the sodium chloride solution into the container, filling it so the nails and braided wires are submerged, but the wire running along the skewer remains above the liquid.
10. The LED should glow faintly. If not, check that the twisted connections are firm.
11. Pick up one skewer in each hand, and move the apparatus so that one nail/braided wire pair is outside the container before immersing again. This is equivalent to taking one lemon battery out of the system.
12. Continue reducing the number of pairs until the LED no longer glows, and you have found the number of lemons you would need to light an LED.



WHAT IS HAPPENING?

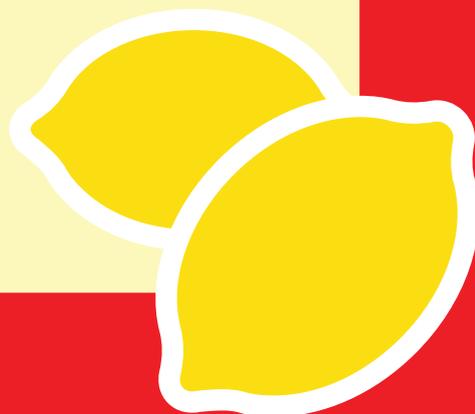
A lemon battery works because of the chemical properties of different metals. Some metals have a greater attraction for electrons than others.

When two different metals are placed in a salty liquid, electrons will flow from one to another (in the liquid, the electrons are carried along on the electrically charged particles of the dissolved salt).

If a wire connects the pieces of metal, the electrons moving between the metals will flow through the wire, and through anything connected to it (like an LED). Movement of the charged particles dissolved in the liquid completes the circuit.

Although the trickle of electrons is too small to light an LED, the Joule Thief circuit works like a dam, releasing the electrical energy in short bursts that have enough power to make the LED glow.

If you use a lemon instead of the salty liquid, the acid in the lemon juice has particles that carry electrons too, but using salty water is less wasteful.



APPENDIX 1: MAKING SOLUTIONS

- Check if what you want to dissolve is in the list of special cases before proceeding.
- Use deionized water for best results, but tap water will work for most things.
- Heat the water to speed dissolving of solids, and stir well.
- After dissolving, carefully pour the liquid solution into a stock bottle and discard any solids that remain (filter if you wish).
- Always label your stock bottles (include the date and safety information).

Copper sulphate (0.5M)

12.5g (about 3 teaspoons) in 100mL water

Iron sulphate (0.5M)

7.5g (about 2 teaspoons) in 100mL water

Manganese sulphate (0.5M)

7.5g (about 2 teaspoons) in 100mL water

Calcium chloride (0.5M)

5.6g (about 1 and 1/3 teaspoons) in 100mL water

Sodium carbonate (0.5M)

4.5g (about 1 teaspoon) in 100mL water

Sodium chloride (0.2M)

1.2g (about 1/4 teaspoon) in 100mL water

Potassium permanganate (0.2M)

3.2g (about 3/4 teaspoon) in 100mL water



SPECIAL CASES

Sodium hydroxide (0.5M)

WARNING: Caustic - will burn skin and eyes - avoid skin contact
Heats strongly when dissolving - dissolve in cold water only
2g (about 1/2 teaspoon) in 100mL cold water

Hydrochloric acid (1M)

WARNING: Highly corrosive - will burn skin - avoid direct contact with skin
Releases corrosive vapour - avoid breathing fumes
Heats explosively if added to water - always add ACID to WATER
Use cold water only
90mL cold water added to 10mL acid

Hydrochloric acid (5M)

WARNING: Highly corrosive - will burn skin - avoid direct contact with skin
Releases corrosive vapour - avoid breathing fumes
Heats explosively if added to water - always add ACID to WATER
Use cold water only, stir while adding
50mL cold water added to 50mL acid



APPENDIX 2: RECIPES FOR SCENTED ESTERS

| ALCOHOL (COMMON NAME) | CARBOXYLIC ACID | ESTER NAME | SCENT |
|-------------------------------------|--------------------|--|--------------------------|
| Propan-2-ol (isopropanol) | Acetic acid | Propan-2-yl acetate | Juicy fruit |
| 1-pentanol (n-amyl alcohol) | Acetic acid | 1-pentyl acetate (n-amyl acetate) | Banana |
| Ethanol (ethyl alcohol) | Formic acid | Ethyl formate | Rum |
| Methanol (methyl alcohol) | Salicylic acid | Methyl salicylate | Wintergreen |
| Ethanol (ethyl alcohol) | Butyric acid | Ethyl butyrate | Pineapple/ Strawberry |
| Butanol (butyl alcohol) | Acetic acid | Butyl acetate | Pear |
| 1-pentanol (n-amyl alcohol) | Butyric acid | 1-pentyl butyrate (n-amyl butyrate) | Pear/apricot |
| Methanol (methyl alcohol) | Butyric acid | Methyl butyrate | Pineapple/apple |
| 2-methylpropan-1-ol (isobutanol) | Formic acid | 2-methylpropyl formate | Raspberry |
| Pentanol (amyl alcohol) | Pentanoic acid | Pentyl pentanoate | Apple |
| Octanol | Acetic acid | Octyl acetate | Orange |
| Benzanol (phenol) | Acetic acid | Benzyl acetate | Jasmine |

