Creating Science – Chemical indicators

Chemicals have many properties, and there are some fun ways to learn what some of them are!

Outcomes

Chemical sciences 4: Natural and processed materials have a range of physical properties that can influence their use (ACSSU074)

Chemical changes 8: Chemical change involves substances reacting to form new substances (ACSSU225)

Science inquiry skills 7: Summarise data, from students' own investigations and secondary sources, and use scientific understanding to identify relationships and draw conclusions based on evidence

Preparation

- Prepare some red cabbage juice. I like to buy a red cabbage (they are actually purple) from the local supermarket (though you may have to look around). Cut it into strips, and freeze it in the freezer overnight so that the water crystallises and breaks up the cell walls. Then just before the start of the lesson add the frozen red cabbage to water and stir (or even better, shake) the purple juice flows out almost instantly. You can boil the cabbage to get the juice out, but freezing is much safer and a lot less smelly.
- Gather some household chemicals, ***being sure to observe all safety requirements that come with the products***. Some very effective chemicals for this activity include: tap water, salt water, water with a teaspoon of bicarbonate soda added, vinegar, fizzy soft drink. Place each in a clear plastic and make sure you have at least five of them. Make sure you use only clear or white substances. Some other chemicals for testing include:
    - Acids: lemon juice, a teaspoon of citric acid, a teaspoon of nitric acid.
    - Antacids (usually): detergent, soap (flakes in water if preferred), human spit, a teaspoon of laundry or dishwasher detergent, antacid tablets, toothpaste.
    - Neutral: salt water, melted snow, milk,
- Some DANGEROUS chemicals that produce extremes include the following. Handle with *extreme* care even if they are obtainable from everyday stores. Do not allow students to handle these materials – the are demonstrations only, and for goodness sake; water them down, open the windows, and have a bucket of emergency water on hand!
    - Caustic soda (NaOH) – also known as Draino. Powerful antacid. Begins green till it turns it a bright yellow, great for careful observation and tricking kids.
    - Hydrochloric acid (HCl) – a nasty acid, hurts your eyes. Available at hardware stores it can be used to clean grease. Wear safety gear, and use **diluted only**. Makes the anthocyanin almost red.
    - Urine. Maybe you shouldn't even try this one…
    - Household bleach. Will turn the antocyanins a deep green, for a only a second, before the bleaching kicks in and kills the colour entirely. Will eventually turn clear.

Class preparation:

Did you know there are many other ways to tell what chemicals we have? Another property which we will be investigating this week is the POWER OF HYDROGEN, also known as pH scale, or more commonly the acid-base reactions. Some fun, and just a little danger, will be involved.

Please bring along;

- a clean and empty pop top bottle (and maybe a spare if you'd like). It can be something similar, but it needs to be about 350ml, clear, clean, and with a sealable lid or you will regret it.

- an art smock or spare t-shirt isn't a bad idea

Looking forward to seeing you all next lesson!

Notes

- This activity potentially involves several chemical substances that are quite dangerous to human health. Observe all safety instructions contained on their labels. Remember it is always wise to wear safety glasses and gloves when dealing with chemicals. Art smocks (or lab coats) may also be helpful to keep clothes and skin clean and clear. *<u>Feel free to avoid using any chemicals you are not comfortable using.</u>*
- Make sure you prepare the anthocyanin solution (red cabbage juice) beginning the night before so that you have plenty to work with. Half a cabbage will easily serve the average class IF students are using small doses of chemicals (i.e., tablespoons and teaspoons, not cups)

Review

Ask students what they learnt about last week, and what they think about atoms.

Remind them at atoms can join together to make substances we call chemicals.

Point out that: all substances are made of atoms, and thus, all substances are made of chemicals. There are MILLIONS of chemical, probably even more. Our body is made from chemicals, the water we drink is a chemical, even the air is *made up* of chemicals. And chemicals are made up of atoms.

Explain:

> We used to say "don't do this at home", but that wasn't very honest – we want kids to try science! But we want them even more to be safe. In science, we like to remember that EVERYTHING IS DANGEROUS – in the wrong place.
>
> Can water kill you? If you try to breathe it in it will! So as long as it's in the right place – safe for drinking – the chemical of water is very safe.
>
> Can fire be helpful? Sure can, for cooking and many other things. But it is NOT SAFE for touching with your skin!
>
> So as long as we HANDLE THE DANGER APPROPRIATLY we will be safe. And to do that, ***we need a grownup***. It's the grownups job to help us manage the danger, and to keep us to keep *ourselves* safe.

Engage

Set up five clear plastic cups 2/3 of the way full with chemicals mentioned in preparation.

Ask:

What do you suppose is in these bottles? How can we find out? They all LOOK like water, but does that mean that they are all definitely water? [No]

Explain:

Remember, while our body can detect using chemicals using taste and smell, some chemicals can be very dangerous! Even a tiny sip can make you incredibly ill. Do not taste our touch chemicals whose nature you are unsure of!

Explore

Give students the student handout.

Explain:

Life is often about balance.

Too much, or not enough, of the right things can be *very* dangerous.

The list on the handout describes something called the pH scale[1]. It is a list on which we can place chemicals in terms of their acidity or their alkalinity.

- Some chemicals are what we call acidic. They taste sour, are corrosive to metals. There are hundreds, if not millions, of different kinds of acids, such as citric acid in fruits, or acetic acid which your stomach makes to help digest food.
- Some chemicals are what we call basic. They are the opposite of acids. They feel slippery. There are hundreds, if not millions, of different kinds of bases, such as sodium bicarbonate for making cakes, or caustic soda for cleaning drains.
- When you mix an acid with a base, they usually cancel each other out and become neutral.

So the ends of the scale are just as dangerous, even though they're the complete opposite chemically. Some acids and bases, especially when heated up, can hurt you very badly.

Some chemicals have special properties that can help us learn about other chemicals. This is one such chemical – red cabbage juice. The special chemical we're talking about is called Anthocyanin.

Experiment:

One at a time, name the chemicals in the cups, and have students predict what colour the red cabbage juice and watch the colour changes.

Ask: why do you suppose that happens?

[1] What does pH stand for? Unbelievably, we're not sure. But the general consensus is "Power of Hydrogen".

Explain

How does this work?

Explain: the red cabbage juice has many ingredients, and one of them gives the cabbage its colour, a chemical called Anthocyanin. This little chemical has an interesting ability to change shape, and therefore, colour depending on its environment. It is called a **chemical indicator**.

- When the environment is acidic, it turns red.
- When the environment is basic (aka an 'antiacid)', it turns green (or yellow).
- When it's somewhere in between, it's purple or blue.

Every chemical is either an acid, or a base, or something in between. Acids are sour and dissolve metal. Bases are slippery to touch. But both strong acids and strong bases are equally as dangerous!

So we can use anthocyanins to tell a little bit about other chemicals.

Elaborate

Activity:

Try seeing what other chemicals around the home, safely managed, are acids or bases.

REMEMBER TO EXERCISE ALL APPROPRAITE ADULT CAUTION. SOME OF THESE CHEMICALS SHOULD **NOT** BE HANDLED BY CHILDREN, BUT MIGHT WORK AS A DEMONSTRATOIN. BE CAREFUL!!!!

For example;

- Soft drink (some as powerful an acid as vinegar)
- Citric acid
- Tartaric acid
- Lemon juice
- Milk
- Clear soap
- Human spit…
- Carbonated mineral water
- Hydrocarbons such as methylated spirits

Anthocyanin <u>isn't</u> in everything

Some chemicals aren't appropriate simply because they are already coloured. For instance, blood is very red, but not because of anthocyanin! Some students may make the mistake of thinking that every red thing is a powerful acid, and that's clearly inaccurate when it's safe to touch and eat all kinds of helpful red things!

Blood is red because of the haemoglobin, but that's another story.

Blood is actually only just a little bit antiacid (basic), but only a little bit!

Try to use only clear or white chemicals.

Activity (DANGEROUS):

Explain:

When you mix an acid with a base, chemical change occurs! It often results in the two chemicals balancing each other out, becoming neutral. For example, mixing acetic acid (vinegar) with bicarbonate soda changes the chemicals, resulting in a chemically neutral solution. It also results in the creation of water and carbon dioxide gas, the latter of which can be used for all sort of uses including making fizzy drinks fizzy or exploding lids of cans! Finally, it's worth knowing that this reaction requires energy from the environment to function, making the surrounding area cooler. Remember - there are loads of other chemical reactions, this is just one!

You need an empty container with a press on lid. Metal containers with easy to press on lids, such as milo or other milk flavouring tins often work well. It needs to be a snug fit: If it's too easy to push on the lid, it'll come off too easily. If it's too hard it might not come off at all (or worse, explode out the side of the can along the seam). If there is a gap in the lid the air will all hiss out before making any impressive explosions. Next, place a handful of bicarb in the bottom of the container. Then place a cup of vinegar, still in the cup, in the milo tin. Press the lid on firmly. Ask students what they will think will happen if you shake the can and mix the chemicals. Have a student test the temperature of the can by touching the base with their whole hand. Then shake it.

WARNING:

depending on your set up this activity can be extremely dangerous. You are, essentially, building a small explosion. The air pressure builds up inside the container until it is powerful enough to push the lid off. Depending on your set up, it may explode open with enough force to break bones, pop eyes, or imbed the lid into the roof of your classroom. **<u>Exercise extreme caution!</u>** For example; point the container away from people, clear an adequate explosion zone, and make sure you don't use a lid so tight the entire container explodes. If the container fails to pop open, wait a while, then carefully leaver the lid off with a screwdriver while standing well away – the container may still be under quite a bit of pressure and the lid may come out quite powerfully. If you hear a hissing sound, the air is likely escaping out from small holes and there will probably be no explosion (try another container). Be careful with this one!!

History of the concept:

So what happens inside the acid-base reactions to make the changes? It took many scientists, over many years, to decide what was happening when acids and bases mix. Now we use the Brønsted-Lowry (1923) definition to explain acids and bases: we think acids give away hydrogen atoms (with one positive charge equivalent to an electron) and bases rip away hydrogen atoms from other chemicals.

Find out more about the history of acid's and bases. You can start here or here.

How accurate do you think this test is?

Ask for suggestions, some may include;

- Are we using completely clean equipment? Maybe the plate, or the air, is slightly acidic or basic and influencing the results!
- It's quite tricky to make colour. Sometimes the printer cannot exactly create the colour we see on the screens. Perhaps a paper is slightly wrong?
- There are different kinds of purple cabbage around the world, perhaps the particular local version has different qualities or quantities of anthocyanin.
- Some chemicals will mix up results because they are **already coloured**. For example, food die is often chemically neutral, but the other colours in the food dye may seem to give you a different result! Is the natural colour of the chemical going to affect the result?
- Maybe the chemicals we are testing aren't very pure? Would pure caustic soda (which is actually very dangerous) be different than the dilute version we used today?
- Sometimes the chemical will not react to the anthocyanin; maybe it cannot dissolve in water or is in particles too large to react very much?
- There are millions of different kinds of chemical indicators. Anthocyanin is a rare chemical in that it gives a full range from acids to bases. Some chemical indicators have a very small range, but they are very accurate over those small ranges.

Remember this is just a simple activity and not a rigorous scientific demonstration. In the end all we can say is that we know the approximate acidity (or otherwise) of a particular substance from this activity, and not exactly how acid/base it is, and ***NOT what the substance actually is!***

But do not despair! As working scientist we would actually:

- do several more tests,
- over dozens of more trials,
- with very precise measurements,

Before we would be willing to commit to an official statement of what chemical we were testing today.

Evaluate

Diagnostic

Find out if students have heard about acids and bases, and what they already know.

Formative

Have students predict what colour a chemical will change before it is mixed with the red cabbage juice. This helps them use their sense of colour, as well as prediction.

Summative

Draw up a chart of chemicals and student results (with accurate colour representations). Have student discuss results, share their conclusion regarding what each chemical was, and **the reasons** they have concluded such.

Creating science

Acids and Bases: chemicals can be organised on the pH scale.

Accurate testing: Scientific tests are often very difficult to make accurate. What reasons could this test described today be inaccurate? What can be done to improve accuracy? Remember the limits of scientific claims: What can be actually conclude from these tests? For example, you could say that substance 4 has the same ph as rain water, so it might be rainwater… but then again, it might not. Appreciating the limits of scientific claims after testing is one of the great learning outcomes of this activity. For example, even after all the tests are done, it is a scientist’s job, and not science in itself, to claim what the substance *actually* is.

Student results

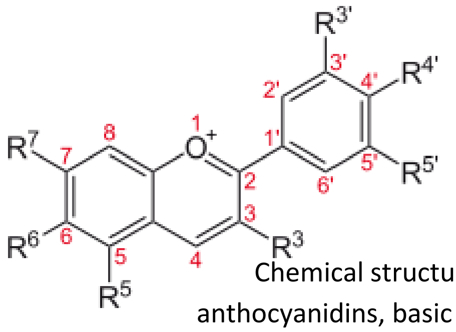
Chemical name	Predicted result (Draw colour)	Actual result (Draw colour)

Chemical Indicators

Chemicals can usually be grouped into two main categories:

Acids taste sour, are corrosive to metals, and become less acidic when mixed with bases.

Bases (or 'antacids') feel slippery and become less basic when mixed with acids.



Chemical structure of anthocyanidins, basic structure of Red cabbage pigment.

Building on the work of others such as the 1800's Swedish chemist Svante Arrhenius, we use the Brønsted-Lowry (1923) definition to explain acids and bases:

Acids are chemicals which can donate hydrogen to other chemicals, while…

Bases are chemicals that can accept hydrogen atoms.

Approximate Red Cabbage colours:

Acids	E.g.,Hydrochloric acid	pH 0	
	E.g., Stomach acid	pH 1	
	E.g., Lemon juice	pH 2	
	E.g., Vinegar	pH 3	
	E.g., Soda	pH 4	
	E.g., Rainwater	pH 5	
	E.g., Milk	pH 6	
Neutral	E.g., Pure water	pH 7	
Bases	E.g., Egg whites	pH 8	
	E.g., Baking soda	pH 9	
	E.g., Tums® antacid	pH 10	
	E.g., Ammonia, (dilute NaOH)	pH 11	
	E.g., Mineral lime	pH 12	
	E.g., Drano®	pH 13	
	E.g., NaOH	pH14	

How can you tell what chemicals at home are Acids and Bases? Make your own chemical indicator using: RED CABBAGE JUICE!

1. **Buy some 'red cabbages'** from the supermarket. You may have to look around, but they're fairly common. You know you're looking at red cabbages because they are purple (!?)
2. **Cut it** into nifty little strips.
3. **Freeze it.** This breaks the cabbage cells and lets the chemicals out more easily. (You can boil it, but hey, if you've got time I always find freezing is safer and much less smelly. Then again, if you like the smell of freshly cooked sauerkraut in your house all day, why not!)
4. Mix your frozen cabbage with some **water** and shake well. You may need to wait a few minutes for the cabbage juices to leak out. The water should turn purple.
5. **Mix it** with some house hold chemicals, and try to guess whether they are acids or bases. A rough guide is given to the left. Remember, below 3 and above 11 are very dangerous: ***avoid!!***

Caution! Some acids are dangerous, and some bases are just as dangerous as acids! – make sure you wear chemical safety gear such as goggles, plastic gloves, and a coat to protect your clothes!