Creating Science – Chemical Indicators

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

#CreatingScienceRedCabbageIndicator

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, and you may find cross curriculum links you can and should use.)

Science understanding

- 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

- 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 (ACSIS130)

Science as a human endeavour

- Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120)

Science vocabulary words

Tier 1 (Everyday words) – chemical, mix, test

Tier 3 (Specialised vocabulary)

- Chemical - the scientific term for 'substance' – all materials are, technically, chemicals, even stone, water and air. All chemicals are made of atoms.
- Acid – a chemical that reacts with a base.
- Base – a chemical that reacts with an acid. (I know I was looking for something more complex, but I kid you not; that's about as precise as a simple answer can get in this case.)
- Alkaline – generally, a base that can also dissolve in water.
- Indicator – a chemical that can be used to tell something about another chemical.

Warning

- 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. *Feel free to avoid using any chemicals you are not comfortable using.*
- 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 or buckets.)

Preparation

- Prepare some red cabbage juice. We 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 cup and make sure you have at least five of them, and fill them up only about 2/3 of the way (leaving room for the Red Cabbage Indicator). Make sure you use only clear or white substances. Some other chemicals for testing include:
    - Acids: lemon juice, a teaspoon of citric acid in water, a teaspoon of nitric acid in water.
    - Antacids: detergent (usually), soap (flakes in water if preferred), a teaspoon of laundry or dishwasher detergent, antacid tablets, toothpaste, human spit.
    - Neutral: salt water, melted snow, milk.
- Some DANGEROUS chemicals might produce extremes in colour, however, handle with *extreme* care even if they are obtainable from everyday stores. Do not allow students to handle these materials – they are demonstrations only, and for safety 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, burns skin. 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.
    - Household bleach. Will turn the anthocyanins a deep green, for a only a second, before the bleaching kicks in and kills the colour entirely. Will eventually turn **clear**.
    - Urine. On second thought, don't even try this one…

Disposal

The chemicals mentioned today are safe to put down the sink.

Red cabbage is fine in the bin, but it's SMELLY in the extreme! Bag it and remove the bin ASAP.

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.

Learning Intent (student friendly)

'We are learning to' (WALT) – detect and describe certain chemicals using a chemical indicator.

Success criteria

'What I'm looking for' (WILF) – using red cabbage juice to make a 'rainbow' of colours.

Student learning goals

Help students make a self-monitored learning goal for this lesson, such as 'learn one clever way to detect new chemicals', or 'find out how to tell acid rain from normal rain'.

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 some red cabbage indicator, use it to label certain chemicals, and then present their findings to the rest of the group.

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 you convenience. Remember, it is not uncommon for students to only remember those points which answered their personal questions.

Younger:

This activity is well suited to this age group. Children at this age can have difficulty with focus. Avoid if you're attempting to make a key point. Manage all materials carefully.

Middle:
You may want to attempt the more dangerous chemicals, with adequate supervision and preparation, with this age group.

Teen:
Try using disposable pipettes to make a more accurate measurement of how much red cabbage indicator is needed to create a measurable result.

Review
Ask students what they think about atoms (See #CreatingScienceSimpleSpectrometry).

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

Point out that: all substances are made of atoms, and thus, all substances are made of chemicals. There are MILLIONS of chemicals, 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:

As science teachers, we used to say "Don't do this at home", but that wasn't very honest – we want kids to try science!

But even more, we want them to be safe. In science, we like to remember that EVERYTHING IS DANGEROUS – in the wrong place, or the wrong time.

- 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 APPROPRIATELY we will be safe. And to do that, ***we need a grownup***. It's **our** responsibility as students to keep ourselves save, and a responsible grownup can really help. It's the grownups job to help **us manage** the danger, but we need to *keep ourselves safe*.

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

Ask: What do you suppose is in these cups? 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 anti-acidity, called 'basic'.

- 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 try to 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. Strong acids and bases, especially when heated up, can hurt you *very badly*.

Some chemicals have special properties that can help us learn about the pH of other chemicals. This is one such chemical that we'll be using today – 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 will be in the chemicals and then watch as the colour changes.

Ask: why do you suppose that happens?

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 with the danger of tasting them!

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

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 DEMONSTRATION. 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 isn't 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 a little bit antiacid (basic), but only a little bit!

Try to use only clear or white chemicals.

How accurate do you think our test is?

Think of ways to Create Science – is our test fair?

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 dye is often chemically neutral, but the other colours in the 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.

History of the concept: Acids and Bases.

Science belongs to people, so who came up with the idea of 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 acids and bases. You can start here or here.

What else is pH useful for?

- All life has a preferred pH level, from plants to people. We use pH to determine the treatment of soil or to make food recommendations.
- Making a swimming pool safe for humans but bad for germs is vital.
- Having 'heartburn' can be treated with an antacid.
- Knowing when otherwise clear water might actually be quite dangerous – i.e., caused by acid rain.

The pH scale is used every day from medicine to environmental management. It's important!

Evaluate

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

Success criteria

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

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?
- Can we tell acids from bases using Red Cabbage Juice?
- How accurate is our test, really?
- Who invented the idea of acids and bases?

Assessment

Prior learning

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 perception, as well as prediction.

Summative

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

So what?

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 imply that the test described today might be inaccurate? What can be done to improve accuracy? Remember the limits of scientific claims: What can be actually concluded 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.

Creating science

Science understanding

As we saw that chemicals can change as we explored the properties of red cabbage juice, we learned that;

- 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

As students carefully, and safely, added red cabbage juice to their mystery chemicals, then used the colour sheet from the activity to make a suggestion about what those mystery chemicals actually were, they were practicing;

- 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 (ACSIS130)

Science as a human endeavour

As we explored red cabbage juice we learnt one way that scientists can use their knowledge to detect unknown chemicals in the environment, which shows us that;

- Solutions to contemporary issues that are found using science and technology, may impact on other areas of society and may involve ethical considerations (ACSHE120)

Hints from the Masters

- Use a wide, flat plate to help see colours clearly, and keep chemicals from getting mixed up.
- While not strictly necessary, gloves and glasses are highly recommended, as the chemicals used today, while not deadly, can be quite painful if they get into a cut or graze.

Student results

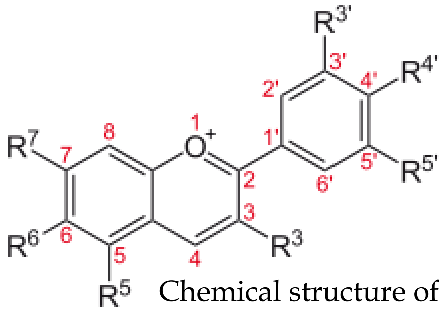
Chemical name	Predicted result (Draw colour)	Actual result (Draw colour)

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 Indicators



Chemical structure of anthocyanidins, basic structure of Red cabbage

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!