Chemistry & The Celts

The Chemistry and the Celts Show is an exciting Science2Life production, specially commissioned by the Northern Ireland Science Festival.

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Introduction to the Chemistry and the Celts Activity Booklet

Welcome to the *Chemistry and the Celts* Activity Booklet, an engaging resource designed for teachers and parents eager to inspire a love of science and culture in children. This booklet builds on the captivating show — which you have hopefully just seen — exploring the rich heritage of the Celts while uncovering fundamental chemistry principles that shape our world.

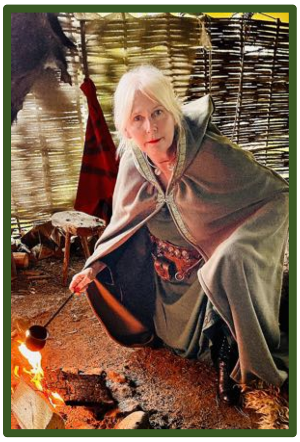
Curiosity and creativity are at the heart of learning, and this booklet serves as a versatile tool for hands-on exploration. Each activity is tailored to different age groups and skill levels, allowing you to select those best suited to your child's interests and abilities. From foundational chemistry concepts to the fascinating connections between ancient Celtic traditions and modern scientific practices, these activities are designed to spark curiosity and encourage critical thinking.

Whether you're a teacher enhancing classroom experiences or a parent seeking fun and educational activities, this booklet is perfect for you. The activities can be integrated into classroom projects, STEAM events, or even birthday celebrations, making learning an exciting adventure.

For those who want to extend the experience, activity kits complementing the themes in this booklet are available from Scientific Sue. These kits are ideal for birthdays, special events, or classroom use. To find out more or to place an order, simply get in touch.

This immersive show, blending science, history, and storytelling, brings the ingenuity of the Celts to life. Proudly supported by **Almac Group, Arts & Business NI**, and the **Navan Centre & Fort**, Armagh, the production explores the remarkable scientific knowledge of the ancient Celts—from metal casting and dyeing to medicine and explosive chemistry! Through engaging demonstrations and hands-on learning, you will discover how Celtic craftsmanship and scientific curiosity shaped the world around them.

About Me



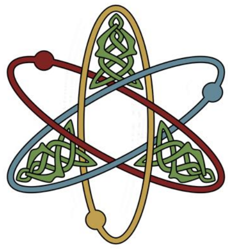
Hi! I am Susan Carvell, affectionately known as Scientific Sue, and I am the founder of Science2Life. My passion lies in inspiring curiosity in the sciences and delivering engaging educational experiences for learners of all ages. I began my career in 1991, teaching Physics and Chemistry. With a keen interest in enhancing educational practices, I completed a Master's in Educational Studies in 1999. In 2000, I transitioned from the classroom to join the founding management team of W5 (who, what, where, when, why) now a globally renowned science centre that opened to the public in 2001.

At W5, I played a crucial role in developing a diverse range of educational programmes tailored to audiences from primary and post-primary students to adult learners. My commitment to advancing physics education led me to join the editorial team for *Physics Education*, the magazine of the Institute of Physics. In recognition of my contributions to the field, I was awarded a **Fellowship of the Institute of Physics**.
I founded Science2Life in 2006, a company dedicated to delivering highly interactive and innovative STEAM shows and workshops. Our programmes have reached audiences across Ireland and the United Kingdom, and we have expanded internationally to countries such as Switzerland, Saudi Arabia, Nigeria, Lebanon, the UAE, and Qatar.

A highlight of my career was in 2015, when I partnered with the **Northern Ireland Science Festival** and the Royal Society of Chemistry to lead a record-breaking class of 1,339 students, setting a **Guinness World Record** for the Largest Practical Science Lesson. Now, ten years later, I am excited to be working on another chemistry-based programme with the NI Science Festival team, titled **The Chemistry and the Celts Show**. This innovative project has a key chemistry partnership with **Almac Group**, a leading global pharmaceutical company based in Craigavon, Northern Ireland. *Almac Group is a global leader in advancing human health and specialises in providing a range of expert services across the drug development lifecycle to pharmaceutical and biotech companies. Their expertise in chemistry is instrumental to the development of new treatments for patients.*, and their expertise in chemistry is instrumental to the success of this programme.

Most recently, in 2023, Science2Life was recognized at the Northern Ireland Enterprise Awards, receiving the award for the Most Innovative Children's Science Workshop Provider in Northern Ireland.

Show Descriptor: The Chemistry & the Celts



Join Scientific Sue on this most historical and scientific journey of discovery!

Step into the Iron Age and embark on an exhilarating journey through science, history, and legend with **Scientific Sue's "The Chemistry & the Celts Show."** This dynamic, hands-on show will transport audiences to a time when druids, warriors, and ancient chemists shaped the world around them using the power of nature and alchemy.

Dressed as a wise druid, Scientific Sue will lead the audience through a series of spectacular experiments, unveiling the secrets of Celtic ingenuity:

🔥 **Forging the Warrior's Weapons** – Witness the dramatic extraction of iron from ore and discover how the Celts used redox reactions to transform raw metal into essential tools, weapons, and treasured coins. One brave volunteer will even cast their very own Celtic coin!

⚔️ **Preparing for Battle** – Meet *Aidan*, our fierce Celtic warrior, as we paint his face using authentic designs inspired by ancient coins. Warriors didn't just fight in drab tunics (well sometimes they didn't wear anything!) – they stood out in battle! Volunteers will help dye cloth using natural pigments, ensuring Aidan is a truly **colourful** warrior.

🌿 **Healing the Wounded** – The battle is won, but Aidan returns with injuries. Using plants, honey, and the power of (slightly smelly!) ancient medicine, we'll explore how the Celts treated wounds, administered pain relief and kept their warriors fighting fit.

🛁 **The Celtic Spa Experience** – War is dirty work! Female warriors were just as fierce as their male counterparts, but after battle, as well as washing a little pampering is in order. Using chemistry and a touch of magic, we'll create colour-changing bath bombs fit for a **Celtic Spa**!

🎇 **Victory & Celebration!** – The raiding party was a success! With grain, cattle, and jewellery now in their possession, the whole village prepares for a grand celebration. Faces are painted, and the bonfire is lit. But as flames dance in the night, disaster strikes—a stray ember drifts into the grain store… *BOOM!* What happens when chemistry and catastrophe collide?

🌀 **Appeasing the Gods** – The gods are furious! Have the Celts' greed angered them? Offerings must be made to restore balance. But who—or what—will be sacrificed? All of Scientific Sue's trainee druids will stand before the audience with everything they've created during the show, and together, the crowd will decide how to appease the ancient spirits.

"The Chemistry & the Celts Show" is an unmissable blend of history, science, and storytelling, packed with fiery explosions, daring experiments, and plenty of audience participation. Whether you're a fearless warrior or a budding druid, you'll leave inspired, entertained, and maybe just a little bit wiser!

THE 6 SCIENCE PROCESS SKILLS

Scientists engage in procedures of investigation to gain knowledge of natural phenomena. The tactics and strategies, the skills scientists use in their pursuit of understanding can be broken down into 6 Science Process Skills, and engagement with the activities in all of **Science2life's STEAM ACADEMY** workshop kits will help to naturally develop these skills within your children:

Observing
This is the most basic skill in science. Observations are made by using the 5 senses. Good observations are essential in learning the other science process skills.
One of the best things we can do for our children's science learning is to help them *observe more closely* – look for more details. **We do this by asking questions**.

Communicating
It is important to be able to share our experiences. This can be done with photographs, videos, graphs, diagrams, maps, and of course, the spoken word.
Observing and communicating those observations go hand-in-hand. Children need to learn lots of adjectives. Words that are used to help describe or give description to people, places, and things. These descriptive words can help give information about size, shape, age, colour, origin, material, purpose, feelings, condition, and personality, or texture.

When talking with a child about what they observe, we often teach new vocabulary.

Measuring
Measuring is important in collecting, comparing, and interpreting data. It helps us classify and communicate with others. The metric system should be used to help understand the scientific world.
Measuring is a special case of observing and communicating. Observing how big something is by measuring it against something else, and then communicating that information to someone else using commonly agreed upon units.

Classifying into Groups/ Sorting
After making observations it is important to notice similarities, differences, and group objects according to a purpose. It is important to create order to help comprehend the number of objects, events, and living things in the world.
One way of classifying is putting things in order say by lining them up from smallest to biggest or sorting them by colour, or if dealing with liquids, runniest to thickest.

Inferring
An inference is an explanation or interpretation based on an observation. It is a link between what is observed and what is already known.
We observe with all five senses, but we interpret what we sense based on our prior experiences and knowledge. Observation results can be called data or facts. **The inference is what those facts mean.**

Predicting
What do you think will happen? It is an educated guess based on good observations and inferences about an observed event or prior knowledge.
Predictions are always based on data. We identify trends in the data which let us predict what will happen. Predictions can be tested: if I do X, does Y happen?

FAIR TESTING

Conducting a fair test is one of the most important ingredients of doing good, scientifically valuable experiments, and is most probably the one most of us remember from our own science lessons.

Change one variable to see its effect on another, whilst keeping all others the same

Fair test questions involve making comparisons, often trying to find out which is the 'best' or 'most'. Through fair testing, children are encouraged to see that one thing has an effect on another, identifying the differences they have noticed and exploring all the variables (any factor subject to change) that may have an effect. Children decide which variable to investigate and how to measure or observe the effects.

In most experiments we usually start with a question; questions suitable for experiment 5 (Making carbon dioxide gas) could be:

- What other household chemicals react with baking soda to produce carbon dioxide gas?
- How can we measure the volume of carbon dioxide produced?
- How does the amount of baking soda affect its reaction with citric acid or vinegar?
- Does the temperature of the water (for citric acid) or vinegar affect the rate of reaction?
- What effect will different vinegars have on the baking soda/vinegar reaction? Will the balloon blow up more?

What are the variables? To answer this, you need to think about all the factors that could change in the experiment. When you carry out the experiment all of these factors should be the same except the one you are testing.

Scientists call the changing factors in an experiment - VARIABLES

So, in a nutshell, fair test experiments require us to observe and measure the effect changing one variable has on another whilst keeping all other variables the same.

The variable you choose to **deliberately change is called the independent variable**. Whilst carrying out the experiment we want to find out what effect this change has on another factor – **we call this factor the dependent variable**.

You can think of the independent variable as being the **'cause'** of the change and the dependent variable as being the '**effect'** that the change you make has during the experiment. In other words, **the dependent variable is the thing that changes as a result of you changing something else.**

Fair testing is not the only key practice a good scientist should know, in fact, there are five approaches that children need to learn to recognise and use: **fair testing; observing over time; pattern seeking; identifying and classifying; and research.**

Introduction to the Celts

The Celts were a diverse group of tribal societies who lived across Europe from around 1200 BCE, during the late Bronze Age. By 600 BCE, their influence had spread across much of Western Europe, including modern-day France, Spain, and Britain.

The Celts began arriving in Ireland around 500 BCE, bringing their distinctive culture, language, and advanced metalworking skills, including iron extraction techniques.

Unlike much of Europe, Ireland retained strong Celtic traditions largely due to Ireland’s island geography shielded it from Roman occupation and many later continental influences. As a result, Celtic culture remained vibrant and well-preserved, deeply influencing Irish language, mythology, and art even to this day.

The word "Celt" comes from the Greek word "Keltoi," which means "the hidden people" or "those who dwell in the woods."

Our knowledge of the Celts today comes from three main sources:

1. **Archaeologists and historians**: These experts piece together the lives of the Celts by studying the artifacts and ruins they left behind. Items such as weapons, jewellery, tools, and household goods provide insight into their daily lives, trade, and cultural practices. Burial sites and fortifications, like hillforts, also reveal their social structures and spiritual beliefs.

2. **Greek and Roman writers**: Ancient texts written by Greek and Roman authors offer valuable descriptions of the Celts, albeit often biased or incomplete. Writers like Julius Caesar, who encountered the Celts during his campaigns, described their customs, warfare, and social organisation. Greek accounts, including those of Herodotus and Strabo, provide additional perspectives, often emphasizing the Celts’ warrior spirit and unique traditions.

3. **Christian scribes**: After the Christianisation of Ireland, monks and scribes began recording the oral stories, myths, and traditions of the Celts. These writings, such as the "Book of Kells" and "Lebor Gabála Érenn" (The Book of Invasions), preserve much of what we know about Celtic mythology and folklore. These sources also reflect the blending of Christian and Celtic traditions, giving a unique view of their evolving culture. However, because the Celts themselves did not write down their history, much of what we know has been interpreted through these secondary lenses.

The Celts in Ireland

The Celts are thought to have arrived in Ireland during the late Bronze Age, around 500 BCE. The name Éire, which is the Irish name for Ireland, comes from the Greek word "Iwernia."

Unlike Britain and the Continent, Ireland’s geographical remoteness prevented colonisation by Rome. Thus, despite regular trade with Roman Britain, the country became a haven for the uninterrupted development of Celtic art and crafts, which were neither displaced by Greco-Roman art, nor destroyed in the ensuing “Dark Ages” (c.400-800).

This led to an unbroken tradition of Celtic culture which retained its own oral, historical and mythological traditions, as exemplified in the Lebor Gabala Erenn (Book of Invasions) –
Many Celtic treasures can be viewed in the ulster Museum and the National Museum of Ireland.

A Greek geographer named Claudius Ptolemy created one of the earliest known maps of Ireland. Initially, the Celts divided Ireland into four provinces, but this later expanded to five.

The Celts were fierce warriors and loved fighting. Clans often attacked their neighbours to steal cattle, jewellery, and even people, who were taken as slaves. These inter-tribal conflicts were a central part of their culture and economy.

The Bronze Age in Ireland

Before the Celts arrived, Ireland was in the Bronze Age, a period marked by significant advances in technology and culture. People in Ireland during this time:

- **Worked with bronze**, an alloy made by combining copper and tin, to create tools, weapons, and jewellery. Bronze tools were sharper and more durable than earlier stone tools, marking a significant leap in efficiency for farming and craftsmanship. Metalworkers demonstrated great skill, crafting intricate designs on jewellery and ornaments.
- **Built impressive structures**, such as stone circles, burial mounds, and fulachta fía (ancient cooking pits). These sites often had ceremonial or communal purposes and show a sophisticated understanding of engineering and social organisation. The burial mounds, in particular, reveal complex rituals surrounding death and the afterlife.
- **Traded extensively**, exchanging goods like tools, ornaments, and raw materials with other parts of Europe. This trade network brought not only wealth but also ideas and influences from other cultures, enriching the Bronze Age society in Ireland. Copper for bronze production was often mined locally, particularly in areas like Ross Island in County Kerry, while tin was imported from regions such as Cornwall in England.

The Celts and the Iron Age

The arrival of the Celts brought the knowledge of ironworking to Ireland, marking the beginning of the Iron Age. This was a pivotal moment in Irish history:

- **Iron tools and weapons** were not only stronger and more durable than those made of bronze but also more accessible, as iron ore was more abundant and easier to source than copper and tin. This shift allowed for widespread production of essential items, transforming daily life and warfare in Ireland.
- The Celts used their advanced metalworking skills to create not only practical tools but also intricate works of art. They crafted swords with decorative hilts, shields adorned with spirals and knotwork, and agricultural tools that increased farming efficiency. Their jewellery, such as torcs and brooches, showcased their exceptional artistic abilities and often indicated social status or tribal identity.
- Their mastery of ironworking represented an important step forward in the development of chemistry. Creating high-quality iron required an understanding of smelting processes, where iron ore was heated in furnaces at extremely high temperatures to remove impurities and produce workable metal. This knowledge demonstrated their ability to manipulate natural materials using heat and other techniques.

The combination of their advanced ironworking skills and their artistic talents made the Celts a unique and influential culture. They blended functionality with beauty, embedding their tools and objects with symbolic designs that carried cultural and spiritual significance. Today, their legacy endures in Irish art, mythology, and traditions, with many Celtic motifs and patterns still celebrated in modern design.

The Celts were incredibly successful in establishing themselves in Ireland, a process that unfolded over several centuries. Some tribes integrated peacefully with the native Irish, fostering alliances and cultural exchange, while others took resources and territory by force. This dynamic history offers us three distinct lenses through which to explore Celtic heritage:

Hill of Tara, Celtic Royal Site in Ireland's Ancient East

The tri-spiral symbol carved on orthostat C10 inside Newgrange

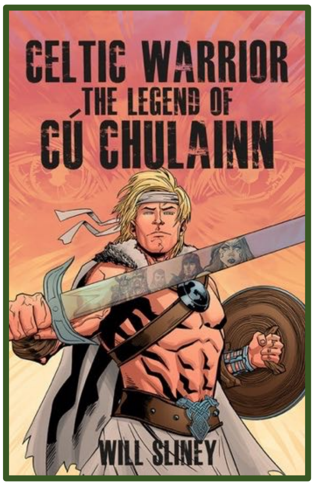
1. **Archaeological and Historical Evidence**: What remains have archaeologists and historians unearthed about Celtic life? These include:

- **Hillforts and Settlements**: Structures like ringforts, crannógs (artificial islands), and hillforts showcase their defensive strategies and community organisation.

- **Tools and Weapons**: Iron tools and weapons, often ornately decorated, highlight their mastery of metallurgy.
- **Art and Jewellery**: Intricate designs in La Tène art style, seen in brooches, torcs, and other jewellery, reflect their artistic sophistication.
- **Burial Sites**: Elaborate graves, often with grave goods such as chariots, weapons, and pottery, provide insights into their beliefs and social structures.
- **Everyday Items**: Fragments of pottery, textiles, and farming tools reveal the practical aspects of Celtic life.

2. **Classical Writings**: How did outsiders, such as Greek and Roman writers, perceive the Celts? Greek and Roman accounts often portrayed the Celts as fierce warriors and barbarians, focusing on their love of battle, drinking, and feasting. Roman writers like Julius Caesar described the Celts as both brave and unruly, highlighting their prowess in combat but often exaggerating their "wild" nature to justify Roman conquests. Greek authors, such as Strabo, also noted their artistry and craftsmanship but viewed their customs as strange or inferior. These descriptions were often biased, reflecting political or cultural conflicts, particularly as the Romans sought to depict themselves as superior and civilised compared to their Celtic adversaries.

3. **Celtic Myths and Sagas**: What stories did the Celts themselves tell, passed down orally and written centuries later by Christian scribes?



- **Heroes and Deities**: Tales of Cú Chulainn, Fionn mac Cumhaill, and the Tuatha Dé Danann illustrate themes of heroism, magic, and the divine.
- **The Otherworld**: Myths often described an enchanting Otherworld, accessible through mounds, lakes, or magical events, and inhabited by fairies and gods.
- **Seasonal Cycles**: Stories tied to festivals like Samhain and Imbolc highlight their connection to agriculture and nature's rhythms.
- **Transformation and Trickery**: Many sagas, such as the tale of Táin Bó Cúailnge (Cattle Raid of Cooley), weave in themes of cunning, betrayal, and supernatural feats.
  Christian monks later recorded these oral traditions, often blending them with Christian symbolism, which preserved the stories but added layers of reinterpretation.

Together, these perspectives paint a vivid picture of Celtic society, blending fact, perception, and legend.

Historical Context Timeline:

- **1200 BCE**: Early Celtic tribes begin to form in central Europe.
- **800 BCE:** Start of the Hallstatt culture, an early Celtic society in central Europe, known for their advanced metalwork and trade.
- **500 BCE:** La Tène culture emerges, spreading Celtic influence across Europe through art, craftsmanship, and trade.

- **400–50 BCE:** Celtic tribes expand into the British Isles and Ireland (marking the transition of the Bronze Age to the Iron Age), establishing strongholds and blending with local cultures.
- **200 BCE**: Peak of Celtic culture in Ireland, with the development of unique art, weaponry, and social structures.
- **43 CE:** Roman invasion of Britain begins, pushing many Celtic tribes further west into Wales, Scotland, and Ireland.
- **100 CE**: Roman accounts describe the Celts as fierce and skilled warriors.
- **400 CE onward:** Christian missionaries arrive in Ireland, recording Celtic oral traditions, myths, and sagas.
- **500 CE**: Christian scribes begin recording Celtic myths, legends, and history.

The Romans never fully invaded Ireland, but they did have interaction with it. Roman expeditions, such as those recorded by Julius Caesar, suggest contact and trade with the Irish around **43-410 CE** during the height of the Roman Empire. The Romans referred to Ireland as "Hibernia" and noted its rich resources, though they did not establish significant settlements.

The **Vikings** arrived in Ireland during the **late 8th century**, around **795 CE**, marking the beginning of the Viking Age. They established settlements, particularly in coastal cities like Dublin, Waterford, and Limerick, which became important trade centres. The Vikings influenced local culture, language, and trade practices.

Time Frame Summary:

- **Celts in Ireland**: Approximately **500 BCE - 400 CE** (into the Early Christian period).
- **Romans in Ireland**: Contact and trade during approximately **43-410 CE**, but no full invasion.
- **Vikings in Ireland**: Arrived around **795 CE** and established settlements until about **1100 CE**.

Cultural Intermingling:

1. **Celtic and Roman Interaction**: The Celts would have encountered Roman goods and ideas through trade. Some Celtic tribes adopted aspects of Roman culture, such as artistic styles and social organisation. The existence of Roman coins found in Ireland indicates trade relations.
2. **Celtic and Viking Influence**: The arrival of the Vikings led to the establishment of urban centres, where Celtic customs blended with Norse traditions. The Irish adopted various Viking technologies, including shipbuilding and trade routes, while the Vikings integrated elements of Gaelic culture, including language and local governance.
3. **Language and Religion**: The spread of Christianity in the 5th century CE, influenced by both Roman and Celtic traditions, further transformed Irish culture. This period saw the merging of pre-Christian beliefs with Christian practices, leading to a unique Irish Christian identity.

Through these interactions and exchanges, the diverse influences of Celtic, Roman, and Viking cultures contributed to the rich tapestry of what is now Irish culture, with its distinct language, folklore, and societal traditions. Why not step back in time and discover Ireland's ancient myths and history at ***Navan Centre and Fort.***

Like myths and legends? You'll love Navan Centre and Fort. Nestled in the scenic County Armagh countryside a short hop from Armagh city, this fascinating archaeological site swirls with wild tales of ancient goddesses and young heroes. Navan Fort was a traditional stronghold of the mythological superwarrior Cú Chulainn and it's said that the goddess of war and fertility Emain Macha (which gives the fort its name) marked out the boundaries here with the pin of her brooch.

Visit and you'll be catapulted back more than 2,000 years to an impressive ceremonial structure that dates to 95AD. As well as the fort itself, there are interactive exhibits and costumed performers, guided Meet the Warriors tours and reconstructed Iron Age dwellings. You'll even get the chance to try some Celtic-inspired spear-throwing! And if you want to take things up a level with some ancient skills, why not opt for a willow weaving or copper-smithing workshop? Going back in time has never been so fun.

Experiment 1: Extraction of Iron from Iron Oxide

Nuts and Bolts

- Spoonful of Iron Oxide (Fe_2O_3) (rust)
- Spoonful of Sodium Carbonate (Na_2CO_3) (Washing Soda)
- Small beaker of water
- 2 Wooden splints
- Bunsen burner / chefs blowtorch / BBQ Lighter
- Safety glasses
- Pestle and mortar / spoon and dish
- Strong magnet
- Cling film

Safety Precautions:

⚠️ **Adult supervision is required** throughout the experiment.

🔥 **Fire safety:**

- Perform the experiment in a **well-ventilated area** and away from flammable materials.
- Keep a **fire extinguisher, fire blanket, or a bowl of water** nearby in case of accidental ignition.
- Ensure long hair is tied back and avoid loose clothing.

🧪 **Chemical safety:**

- **Sodium carbonate** can cause skin and eye irritation—**wash hands** after handling.
- **Iron oxide** should not be inhaled—avoid creating dust while mixing.

🛑 **Heat safety:**

- The splint will become extremely **hot**—allow it to **cool completely** before handling.
- Use **heat-resistant gloves or tongs / tweezers** to prevent burns.

🧲 **Magnet safety:**

- Small iron particles can be sharp—keep away from eyes and mouth.
- Wrap the magnet in **cling film** to prevent difficult-to-remove iron filings from sticking.

Secrets for Success

1. **Prepare the Splint:**
    - Soak the wooden splint in water for a few minutes until it is thoroughly damp. The splint end has to be thoroughly soaked before coating it with the powder to prevent the splint from burning away too quickly.
2. **Prepare the Chemical Mixture:**
    - Mix equal amounts (**1:1 ratio**) of sodium carbonate and iron oxide.
    - Use a pestle and mortar to grind them together until fully blended.
3. **Coat the Splint:**
    - Remove the splint from the water and dip the tip into the powdered mixture, ensuring it is well coated. Make sure the splint is properly coated – if too little powder is applied the reaction may not release enough iron.
4. **Heat the Splint:**
    - Hold the coated tip in a **hot Bunsen burner flame** and heat it strongly.
    - You **cannot overheat it**, but the uncoated section of the splint may burn away, causing the tip to drop off—this is not a problem just lift it with tweezers on to the dish you are going to use for grinding.

5. **Chemical Reaction Explanation:**
   - The **iron oxide is reduced to metallic iron** by the carbon from the splint.
   - The sodium carbonate melts, allowing the iron oxide to penetrate deeper into the splint, increasing contact between the carbon and the iron oxide.

6. **Cooling and Grinding:**
   - Allow the tip to cool for a few seconds.
   - Use the **back of a spoon** or the **pestle and mortar** to grind the burned tip into a fine powder.

7. **Testing for Iron:**
   - Wrap a **magnet in cling film** to prevent iron particles from sticking permanently.
   - Dip the magnet into the powdered mixture—if iron has been extracted, **particles will stick to the magnet**.
   - Iron is the only common metal that is significantly magnetic, confirming its presence.

Science in a Nutshell

Iron is relatively unreactive, meaning its oxide can be reduced to the metal when heated with carbon. In this experiment, you will extract iron from the iron oxide using a wooden splint as the carbon source – mimicking, on a small scale, the processes used by ancient metal workers, including the Celts, who were highly skilled in **iron smelting and metalworking**

Connecting This Experiment to the Celts

The process you have just completed is a **miniature version of what the Celts did on a much larger scale**. They discovered that by heating **iron ore** with **charcoal** (a carbon source), they could extract **pure iron**.

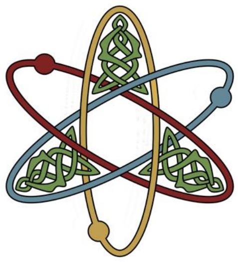
- **Bloomery Furnaces:** The Celts built **bloomeries**, which were clay or stone furnaces that reached high temperatures, allowing the reduction of iron ore into **spongy, workable iron**. This is similar to how your **splint and carbon source** reduce iron oxide to iron in this experiment.
- **Weapons and Tools:** Once extracted, the Celts used **forges** to shape the iron into **swords, shields, farming tools, and jewellery**, refining their techniques over centuries.
- **Mastering Fire and Chemistry:** They understood that adding certain materials (like the **sodium carbonate in our experiment**) could help control the process, making it more efficient—just as you saw the sodium carbonate help transport the iron oxide in your experiment.

By performing this experiment, you are **replicating a fundamental part of Celtic metalworking**, gaining insight into how ancient societies advanced through their understanding of **science, chemistry, and engineering**.

Why is Carbon Used to Reduce Iron Oxide?

To understand why **carbon** is used to extract **iron** from iron oxide, we need to look at the **reactivity series**—a list of metals arranged by how easily they react with other elements.

The Reactivity Series (Simplified)



Most Reactive	Sodium (Na)
	Magnesium (Mg)
	Aluminium (Al)
	Carbon (C)
	Zinc (Zn)
Iron (Fe)	↓ **Iron is here** ↓
	Copper (Cu)
Least Reactive	Gold (Au)

From the table, we can see that **carbon is more reactive than iron**. This is the key reason why carbon can be used to **extract iron from iron oxide**.

How Does Carbon Reduce Iron Oxide?

- Iron exists in nature as **iron ore** (mainly iron oxide, Fe_2O_3).
- In the extraction process, carbon is used as a **reducing agent** because it can **take away oxygen** from iron oxide, leaving behind pure **iron metal**.

👉 **Word equation: Iron oxide + Carbon → Iron + Carbon dioxide**

👉 **Symbol equation:** $\mathbf{Fe_2O_3 + 3C \rightarrow 2Fe + 3CO_2}$

The carbon reacts with the oxygen in iron oxide, forming **carbon dioxide** and leaving behind **pure iron**. This is called a **reduction reaction** because oxygen is **removed** from the iron compound.

Why Can't Other Metals Be Used Instead of Carbon?

- **Metals higher in the reactivity series than carbon** (e.g., aluminium, magnesium) are too reactive to be displaced by carbon.
- **Metals lower in the reactivity series than carbon** (like copper) do not require carbon at all—they can be extracted simply by heating their ores.

This is why, for thousands of years, humans have used **carbon (in the form of charcoal) to extract iron**—just as the **Celts** did in their bloomeries!

Magnetism and Magnets

Magnetism is an invisible force, caused by the electrons in the atoms that make up everything around us.

A magnet is an object that has a magnetic field (an invisible pattern of magnetism).

Magnets come in different shapes and sizes but they all have a south seeking pole and a north seeking pole – we usually just say south pole or north pole.

- Opposite poles attract: this means the north pole of one magnet will attract (pull towards) the south pole of another magnet.
- Like poles repel: this means that the north pole of a magnet repels (pushes away) the north pole of another magnet and the south pole of a magnet repels (pushes away) the south pole of another magnet.

Objects which contain the elements iron, nickel or cobalt will be attracted (pulled towards) to a magnet. We can only get an object to be pushed by a magnet if that object itself is also a magnet and the facing poles are the same; north-north or south-south.

The Earth is a giant magnet, this means there is a magnetic field all around us. The north (seeking) pole on a magnet or a magnetized compass needle is often coloured red.

The opposite poles of two magnets are attracted. Therefore, when the red end of a magnet or compass is pointing north, it is because it is being attracted in that direction by the south end of another magnet (often coloured blue). So, when we think of the Earth as a big magnet, it is the south pole of the magnet that is underneath the North Pole of the Earth – The North Pole is actually a south seeking pole!

The means that the Earth's North Magnetic Pole is actually a magnetic south pole and the Earth's South Magnetic Pole is a magnetic north pole!

The Compass

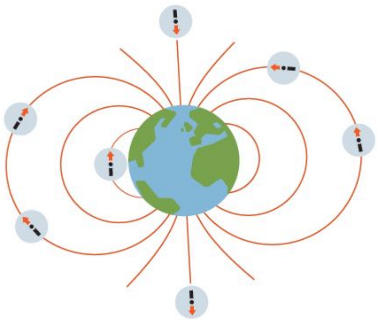
A compass comprises:

- a magnetic needle mounted on a pivot (so it can turn freely)
- a dial to show the direction
- Using compasses, we can map the direction of the magnetic field lines surrounding a magnet.

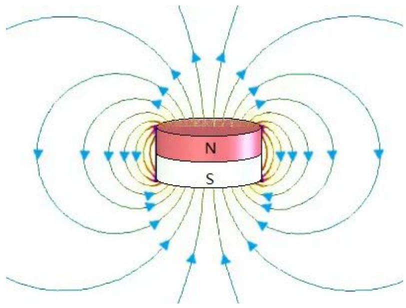
The north pole (north-seeking pole) of the compass needle points towards the Earth's North Pole. If the needle points to the N on the dial, you know that the compass is pointing north. This lets you navigate outdoors using a map.

Earth's Magnetic Field

Magnets are simple examples of natural magnetic fields. But guess what?
The Earth also has a huge magnetic field, due to the core of our planet being filled with molten iron (Fe).



The Earth's magnetic field affects the needles in compasses.



This large magnetic field protects the Earth from space radiation and particles such as the **solar wind**. When you look at tiny magnets, they are working in a similar way.

Celts and Magnetism

The Celts likely had a rudimentary knowledge of magnetism, though not in the scientific sense we understand today. Their awareness of magnets would have come from natural observations and interactions with magnetite, a naturally occurring magnetic mineral (also known as lodestone). Here's what they might have known:

1. Natural Magnetism
    - The Celts may have encountered magnetite in areas where it occurs naturally. They might have noticed its ability to attract iron-rich materials, such as small pieces of iron or iron ore.
2. Magnetism and Mythology
    - Given their deep connection to nature and spirituality, the Celts might have attributed mystical or magical properties to magnetism. They could have associated the lodestone's "invisible force" with the power of the Earth, gods, or druidic energy.
3. Tools and Navigation
    - There is no evidence to suggest that the Celts used lodestones for navigation as the Chinese did (e.g., for primitive compasses), but they might have experimented with these stones out of curiosity or used them in symbolic or ritualistic practices.
4. Mining and Metallurgy
    - The Celts were skilled metalworkers, excelling in iron, bronze, and gold crafting. If they encountered magnetite in mining iron ore, they may have noticed its unique properties and possibly experimented with its effects during their metallurgical processes.
5. Druidic Lore
    - The Celts were known to incorporate observations of nature into their lore and practices. Magnetism might have been referenced metaphorically in their oral traditions, symbolizing attraction or unseen forces.

While they lacked a scientific framework to explain magnetism, the Celts' experiential understanding of nature and their curiosity about unusual phenomena likely made magnets an intriguing part of their world. You could tie this into your show by demonstrating simple experiments with magnetite, showcasing how the "invisible force" might have captivated Celtic artisans or druids.

properties of iron are often introduced with practical experiments using magnets and iron filings.

Experiment 2: Celtic face painting activity – using woad

Introduction:

The Celts were known for painting their **faces and bodies** using natural dyes like **woad**, especially in battle or for ceremonial purposes. Archaeological finds, including **Celtic coins**, depict warriors and individuals with intricate painted designs, giving us insight into their artistic and cultural traditions. Woad (*Isatis tinctoria*) has been historically significant as a natural dye, known for producing a rich blue colour. This biennial plant was widely cultivated by the Celts in Europe and Britain, where it was used for dyeing textiles and as body paint. Woad leaves were harvested in the plant's first year of growth, then processed through fermentation, dried, and transformed into a paste or powder for dyeing.

The Celts, renowned for their use of woad-derived blue, painted their bodies for battle, social events, and rituals. Julius Caesar noted that British Celts used blue body paint to intimidate their enemies, linking it to warfare. Beyond battle, it held social and spiritual significance, often forming body patterns tied to tribal identity. Despite being caustic and prone to flaking, woad's artistic and cultural importance kept it central to Celtic life.

Woad was also important in medieval Europe's textile industry, serving as the main blue dye until it was replaced by indigo in the 17th century.

In this activity, children will use **face paints** to recreate **Celtic-inspired designs**, connecting them to ancient traditions while learning about the chemistry behind natural dyes.

Nuts and Bolts

- Blue and green **face paints** (to mimic woad's colour variations)
- Small **paintbrushes or sponges**
- **Water and wipes** (for cleaning brushes and skin)
- **Reference images of Celtic coin designs** (to inspire patterns
- **Mirrors** (so children can see their work)

Safety Precautions:

When using face paints, especially for children, it's important to follow these safety precautions to ensure a fun and safe experience:

1. **Allergy Test:** Before applying face paint, perform a patch test. Apply a small amount of paint to a discreet area of skin and wait 24 hours to check for any adverse reactions such as redness, itching, or swelling.

The "**Mšecké Žehrovice Hero**" is a late 2nd Century BCE or early 1st Century BCE limestone bust of a **Celtic warrior**. The male figure wears a **Celtic torc** necklace, and has stylized facial features which include a curved moustache and brow. This stone head is one of the most reproduced and iconic examples of **ancient Celtic art**.

2. **Use Skin-Safe Products:** Only use face paints that are specifically formulated for skin use. Avoid craft paints, as they can contain harmful chemicals.

3. **Clean Skin:** Ensure the child's face is clean and dry before applying face paint. This helps prevent skin irritation.

4. **Avoid Sensitive Areas:** Be cautious when applying paint near the eyes and mouth. If using paint around these areas, choose products specifically designed for those regions.

5. **Supervision:** Always supervise children during the face painting process to avoid accidental ingestion of paints or mishaps.

6. **Application Tools:** Use clean brushes or sponges for application to prevent the spread of germs. Never share applicators between different children.

7. **Timing:** Limit the duration of wearing face paint to prevent irritation. Remove the face paint after a few hours.

8. **Removal:** Use gentle soap and water to remove face paint. Avoid harsh chemicals or scrubbing that might irritate the skin.

9. **Storage:** Store face paints in a cool, dry place and check for expiration dates. Do not use products that are past their expiration.

10. **Consult Guidelines:** If unsure, check the manufacturer's guidelines for specific safety recommendations.








Images by Stefan Lofving

By following these precautions, you can ensure a safe and enjoyable face painting experience!

Secrets for Success

1 Introduction to Celtic Face Painting:

- Show images of **Celtic coins** that depict face and body paint.
- Discuss how Celts used **woad**, a plant-based dye, for **ceremonial, tribal, and battle markings**.

2 Choose a Design:

- Provide children with **simple examples** of Celtic-inspired designs:
    - **Swirls and spirals** (symbolising nature and cycles of life)
    - **Dots and lines** (seen on ancient artefacts)
    - **Animal symbols** (inspired by Celtic mythology)
- Encourage them to **create their own patterns**, using the coin imagery for inspiration.

3 Painting the Designs:

- Using a **small brush or sponge**, apply **blue and green** face paint in chosen patterns.
- Start with **simple shapes** and add details **layer by layer**.
- If comfortable, children can **paint each other's faces** for a fun group experience!

4 Science Link – Why Did the Celts Use Woad?

- Explain that **woad contains indigotin**, the same natural pigment found in indigo dye.
- Unlike face paints today, woad required a **chemical process** to extract the blue colour.
- Discuss how **chemistry and artistry** were deeply connected in Celtic culture.

Comparing Two Methods for Making Woad Body Paint

A Science and History Investigation

Wood (Isatis tinctoria) was used by ancient Celts to create blue body paint, but simply mixing woad powder with water does not produce a bright blue. Two different chemical methods can be used to develop the blue pigment: an **alkaline reduction process** (traditional method) and an **acid-based quick method**. This experiment allows students to compare these techniques and explore the chemistry behind woad dyeing.

Method 1: Alkaline Reduction (Historical Process)

Goal: Extract and develop indigo pigment through reduction and oxidation.

Nuts and Bolts

- 10g woad powder
- 200ml warm water (~40°C)
- 2g (½ tsp) sodium carbonate (washing soda)
- 3g (¾ tsp) ascorbic acid (vitamin C) OR fructose
- Optional: 1-2 drops ammonia
- Stirring rod or spoon
- Container with a lid

Secrets for Success

1. Mix **woad powder** with **warm water**.
2. Add **sodium carbonate** to create an alkaline environment (pH ~9–10).
3. Stir in **ascorbic acid or fructose** to remove oxygen (reducing agent).
4. Cover and let sit for **1 hour** in a warm place. The liquid should turn yellow-green.
5. Apply to the skin. It will **oxidize to blue** when exposed to air.

Science in a Nutshell

- Woad contains **indican**, which breaks down into **indoxyl** under alkaline conditions.
- Without oxygen, indoxyl remains soluble and appears **yellow-green**.
- When exposed to air, **oxidation converts indoxyl into indigotin (blue pigment)**.

Pros: ✅ Produces a **deep, long-lasting blue** ✅ Historically accurate ✅ Demonstrates oxidation-reduction reactions

Cons: ❌ Takes time (1 hour preparation) ❌ Requires careful pH control

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Method 2: Quick Acid-Based Woad Paint

Goal: Activate pre-existing pigment for immediate use.

Nuts and Bots

- 10g woad powder
- 100ml warm water
- ½ tsp vinegar OR ¼ tsp citric acid
- 2 drops rubbing alcohol or glycerine (optional, for better consistency)
- Stirring rod or spoon

Secrets for Success

1. Mix **woad powder** with **warm water** to form a paste.
2. Stir in **vinegar or citric acid** to help release pigment.
3. Apply directly to skin. The colour may appear **green at first** but should deepen to **blue** as it dries.

Scientific Explanation:

- Some indigotin (blue pigment) is already present in woad powder.
- Acid **helps release pigment particles** from plant residues.
- As the paint dries, oxidation can still cause **some deepening of the blue colour**.

Pros: ✅ **Fast and simple** (ready in minutes) ✅ No need for pH control ✅ Great for quick classroom activities

Cons: ❌ May not develop as strong a blue as the alkaline method ❌ Can fade more quickly over time

Comparison Table: Woad Paint Methods

Feature	Alkaline Reduction	Acid-Based Quick Paint
Preparation Time	~1 hour	A few minutes
Color Development	Slow but deepens	Fast but may fade
Scientific Process	Reduction & oxidation	Acid pigment activation
Historical Accuracy	✅ Yes	❌ No
Difficulty Level	More advanced	Easier
Best For	Deep blue results, chemistry lessons	Quick activities, body painting

Discussion Questions

1. Which method produces the strongest blue colour? Why?
2. Why does the alkaline method require time to develop?
3. What role does oxidation play in both methods?
4. How might the Celts have discovered this process without modern chemistry?

Extension Activities

- **Test different pH levels**: Use pH strips to measure how acid or alkaline solutions affect colour development.
- **Speed up oxidation**: Use a fan or blow on the paint to see how quickly the colour changes.
- **Compare woad to other natural dyes**: Try experiments with turmeric (yellow), beetroot (red), or cabbage (pH indicator effects).

This experiment blends **science, history, and art**, making it a fantastic hands-on learning experience. Enjoy your woad investigations!

Science in a Nutshell

The use of woad (Isatis tinctoria) as a dye, particularly in Celtic times, involves some interesting chemistry.

Chemistry of Woad as Face Paint

1. **Source of Dye:** Woad is a flowering plant whose leaves contain a natural dye known as indigo. The key compound responsible for the blue colour is indigotin.
2. **Extraction Process:** To extract the dye, the leaves of the woad plant are harvested, fermented, and processed. When the leaves are crushed and mixed with water, they begin a fermentation process that converts the precursor compound, indican, into the soluble form of indigo.

3. **Oxidation and Reduction:**
   The transformation of indican to indigo involves both oxidation and reduction reactions:
   - **Reduction:** During fermentation, the indican is reduced to form indoxyl. This step typically involves losing an oxygen atom and acquiring hydrogen.
   - **Oxidation:** When the indoxyl is exposed to air after being applied to the skin, it undergoes oxidation. This reaction involves the addition of oxygen, converting the reduced form of the dye (indoxyl) into the insoluble pigment (indigotin), which gives it the characteristic blue colour.
4. **Application as Face Paint:**
   Once the indigo is formed, it can be mixed with a binding agent (like fat or oil) to create a suitable face paint. When applied to the skin and exposed to air, the oxidation process continues, solidifying the dye in place.
5. **Durability and Colour-fastness:** The resultant indigo pigment is noted for its durability and resistance to fading, making it an ideal choice for face paint in various cultural practices, including the Celtic traditions.

Conclusion

The chemistry behind using woad as a face paint illustrates a fascinating interplay of biological processes and chemical reactions. The steps involving oxidation and reduction are crucial for developing the vibrant blue colour that was significant for Celts in rituals and decorations.

This historical perspective not only highlights the practical uses of natural materials but also showcases how ancient peoples engaged with chemistry long before the field was formally recognised.

***Art Activity:** Celtic Face Art –- Recreate the Ancient Designs!*

Instructions:

1. Look closely at the four Celtic coins showing heads with unique face designs. These patterns may have been used for decoration, symbolism, or even war paint!
2. Observe the shapes, lines, and details carefully. What patterns do you see? Are there swirls, dots, or bold markings?
3. Using a pencil or coloured pens, copy the designs from the coins onto the blank heads opposite them. Try to match the details as closely as possible.
4. Once you've finished, compare your drawings to the original designs. Do they look similar?
5. (Optional) Create your own Celtic-inspired face design on a separate piece of paper—what symbols or patterns would you use to represent yourself as a Celtic warrior or leader?

Fun Fact: Some historians believe the Celts painted their faces with natural dyes like woad before battle to intimidate their enemies!

Art Activity: Styrofoam Self Portraits

Objectives:

- Encourage creativity and self-expression.
- Explore cultural artistry by drawing influence from Celtic designs.

Materials Needed:

- Styrofoam head
- Skin-toned craft paint
- Various colours of paint (for eyes, cheeks, mouth, etc.)
- Paint brushes in varying widths
- Craft materials for decoration (hair, jewelry, etc.)
- Glue and scissors
- Optional: fabric scraps, feathers, beads, sequins, or stickers

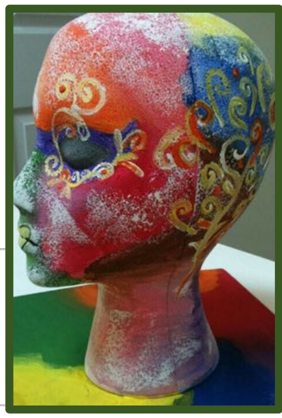
Suggested Order of Activity:

1. Prep Your Workspace:
   - Set up a clean, flat surface for painting and decorating. Lay down newspaper or a plastic tablecloth for easy clean up.
2. Base Coat:
   - Begin by painting the entire Styrofoam head with skin-toned craft paint. Allow to dry completely.
3. Facial Features:
   - Paint the eyes, including the iris and pupil. Use smaller brushes for detail.
   - Add cheeks with a dash of blush colour.
   - Paint the mouth, and consider adding freckles with a fine brush.
   - Allow each layer of paint to dry before moving on or adding additional details.
4. Hair:
   - Use various craft materials to create hair. This could include yarn, fabric, or paper. Encourage children to be creative with colours and styles, representing their own hairstyle.
5. Jewellery and Accessories:
   - Use glue to attach craft materials for earrings, necklaces, and hair accessories.
   - Consider allowing children to create DIY jewellery with beads or stickers.
   - For glasses or sunglasses, they can create frames from paper, cardboard, or pipe cleaners.
6. Final Touches:
   - Once everything is assembled and dried, let the children decorate their heads with additional items, such as ribbons for headbands or decorative stickers.
   - Encourage them to personalize their head even further by adding favourite colours or patterns.
7. Showcase Your Work:
   - Once the heads are complete, the children can showcase their creations with their favourite hat on the Styrofoam head.

- Consider setting up a mini-exhibition where kids can display their heads and explain the choices they made.

Additional Ideas:

- Themed Portraits: Encourage children to theme their self-portrait based on Celtic history, incorporating symbols or patterns they learned about.
- Creative Packaging: Once finished, children can design a small box or bag to store their Styrofoam head after use.
- Reflection Activity: After the project, have a group discussion where children can share their favourite part of the creation process and what they learned about Celtic culture.



This activity encourages creativity while allowing children to express themselves through art.

Woad Dyeing

Connecting Chemistry to Ancient Craftsmanship

We have definite evidence that the Celts used the woad plant for dyeing, but as the process is time-consuming, this booklet's dyeing activity will use red cabbage pigment instead. However, the traditional wood-dyeing method is fascinating, and for those of you who want to try dyeing cloth the old-fashioned way, I have included this section on woad dyeing for you to explore.

Woad Dyeing Process: The traditional method of woad dyeing involves the fermentation of urine to create an alkaline solution that aids in the extraction of the indigo pigment from woad leaves. This process involves both reduction and oxidation reactions, which are key to understanding the colour changes in the dyeing process.

To simplify this method for classroom demonstrations while maintaining historical accuracy, the following steps are used:

*1. **Harvesting the Woad Leaves***
The first step involves harvesting the leaves of the woad plant (*Isatis tinctoria*). The dye compound **indigotin**, responsible for the blue colour, is not directly present in the fresh leaves but exists in a precursor form called **indican** (a glycoside).

- **Indican** is a compound bound to a sugar molecule, making it water-soluble and inactive in its original state.

*2. **Extracting the Pigment***
To release the dye, the leaves are crushed and simmered in hot water to create “woad tea”, then strain it to separate the plant material
This step activates **enzymes** naturally present in the leaves, such as **beta-glucosidase**, which breaks down indican into:

- **Indoxyl** (a colourless compound)
- **Glucose** (a by-product of breaking the glycosidic bond).

Add sodium carbonate to the liquid to make it alkaline, mimicking the traditional use of URINE.

- The water becomes yellow-green due to the accumulation of **indoxyl**.

*3. **Precipitating the Dye:***
Shake the solution to oxidise the pigment. After shaking, the blue pigment will collect at the bottom of the bottle.

*4.. **Preparing the Dye Vat:***
Use a reducing agent (like fructose or yeast) to create an oxygen deprived environment, turning the pigment into its soluble ‘indigo white’ form.
Soak the fabric in the dye vat. When removed and exposed to air, the fabric will turn blue, showing oxidation at work.

*5. **Collection and Use***
To isolate the dye:

- The blue precipitate is collected by filtering or skimming it from the surface.
- It is then dried into a powder or paste, which can be rehydrated or mixed with other substances (like fats or waxes) to make body paint, or dissolved in an alkaline solution for fabric dyeing.

Why the Oxidation Step is Crucial

Without oxidation, the dye remains in its precursor form (indoxyl), which is water-soluble but colourless. Oxidation not only produces the vibrant blue indigotin but also makes it insoluble, allowing it to adhere to fibres permanently.

Experiment 3: The Blue Bottle Experiment

The Blue Bottle Experiment is a quick and fascinating demonstration of oxidation and reduction reactions using methylene blue in a glucose solution. It illustrates fundamental concepts of chemistry relevant to the dyeing process with natural dyes like woad.

Nuts and Bolts

- Methylene blue dye 1-2 ml (0.1% solution)
- Glucose (dextrose) powder 10 g
- Water 100 ml
- Sodium hydroxide (lye) 1-2 g solid crystals or 0.5 ml concentrated NaOH solution – Use caution and appropriate safety measures
- A clear bottle with a cap

Safety Precautions

- Ensure to handle all chemicals with care, wearing gloves, goggles, and a lab coat as appropriate.

- Methylene blue can stain skin and clothing, so handle with caution.
- Adjust the concentrations as needed for educational purposes, especially if working with younger students.
- Store equipment out of the reach of children under 12 years of age.

By using these quantities, the experiment can be conducted efficiently while demonstrating redox reactions effectively. Always ensure to follow safety guidelines when working with chemicals.

Secrets for Success

1. In a clear bottle, mix the water, glucose, and sodium hydroxide thoroughly.
2. Add the methylene blue solution and shake well to ensure everything is well mixed.
3. Seal the bottle and observe the initial blue colour.
4. Allow the bottle to sit and observe the colour change as it fades and then regains colour when shaken – demonstrating the reversible nature of the reaction.

Disposal
Dispose of solid waste along with household rubbish. Pour solutions down the sink. Wash with an excess of water.

Science in a Nutshell

Understanding the Oxidation – Reduction (redox) Reaction

Oxidation is the **loss of electrons**, the **gain of oxygen**, or the **loss of hydrogen**, while reduction is the **gain of electrons**, the **loss of oxygen**, or the **gain of hydrogen**. In this experiment, **glucose is oxidised** because it **loses electrons**, and **oxygen is reduced** because it **gains electrons**. However, glucose cannot transfer its electrons directly to oxygen, so an **electron carrier** is needed—this role is played by **methylene blue**.

Methylene blue **accepts electrons** from glucose, causing glucose to be **oxidised**. Methylene blue is **reduced** in the process and turns colourless. It can then transfer these electrons to **oxygen**, allowing oxygen to be **reduced**. However, this reaction only occurs in an **alkaline** solution.
Chemical Reaction

The Blue Bottle Experiment works through a redox reaction:

- **Reduction Reaction:** Methylene blue (oxidized form) is reduced by glucose, thus losing its colour.
  Methylene Blue (blue) + Glucose → Leucomethylene Blue (colourless) + Oxidised Glucose
  However, once **all the oxygen in the solution is used up**, methylene blue has nowhere to pass its electrons. It remains in its **colourless, reduced form**, unable to return to its blue, oxidised state.
- **Oxidation Reaction:** When the mixture is agitated, oxygen in the air dissolves into the solution, providing a new supply of **electron acceptors**. Methylene blue can now **transfer its electrons to oxygen**, allowing it to be **oxidised** back to its **blue** form.

  Leucomethylene Blue (colourless) + O_2 → Methylene Blue (blue)

However, this process cannot continue indefinitely. If the flask is sealed, all the available **oxygen** will eventually be used up, and the solution will remain **colourless**, even when shaken. To restart the reaction, we must **open the flask**, allowing fresh oxygen to dissolve in the liquid.

Why Did We Add an Alkali to the Glucose Solution?

To allow the reaction to proceed, we added **sodium hydroxide (NaOH)**, creating an **alkaline environment**. Methylene blue can only accept electrons in these conditions. Without NaOH, glucose would still try to **donate electrons**, but methylene blue would be unable to **accept them**, meaning the reaction would not occur and the solution would stay **blue**.

Connection to Woad Dyeing

Using the principles demonstrated in the Blue Bottle Experiment, we can draw parallels to the oxidation and reduction processes involved in dyeing with woad:

1. **Woad Dye Process:**
   - In woad the dye starts in a reduced state when it comes from the plant and is water-soluble.
   - When applied to fabric, it is oxidised upon exposure to air, solidifying into the insoluble blue pigment that gives the fabric its colour.
2. **Time Frame Limitations:**
   - The Blue Bottle Experiment can be executed quickly, showcasing the immediate redox changes in a visual and engaging way, which is not feasible with traditional woad dyeing. The process of dyeing fabric with woad involves several steps:
     - **Extracting the Dye:** Harvesting and processing the woad leaves takes time.
     - **Fermentation:** The fermentation of leaves to form indigo can take several hours to days.
     - **Dye Application:** The application itself can also be time-consuming, as the fabric must be dipped and allowed to oxidize properly.

Conclusion

While the Blue Bottle Experiment provides a quick and insightful demonstration of oxidation and reduction reactions, traditional woad dyeing is significantly more involved, taking much longer due to the intricate steps necessary to produce and apply the dye. Therefore, while a live demonstration might effectively illustrate the concepts, it may not reflect the time-consuming nature of dyeing with woad. This contrasts with the immediacy of the Blue Bottle Experiment, making it suitable for educational settings where time is limited.

Historical Use of Fermented Urine in Dyeing:

Fermented urine played a significant role in dyeing processes across various cultures and time periods, demonstrating the ingenuity of early chemists in utilising readily available materials. It was valued for several reasons: its fermentation produced ammonia, which acted as a mordant to help natural dyes adhere to fibres; it enhanced dye fixation when used with various plant materials, as seen in ancient cultures including the Celts; and it was a cost-effective resource, making it a practical choice in textile production.

Ancient Rome
The Romans utilised fermented human urine, known as *lant*, in textile processing. Fullers, responsible for cleaning and finishing cloth, used urine to remove grease stains from clothing and to prepare wool for dyeing. The ammonia in urine acted both as a cleaning agent and as a mordant, enhancing dye adherence to fibres. Recognising its industrial value, Emperor Vespasian famously imposed a tax on urine collection, giving rise to the phrase *Pecunia non olet* ("money does not smell").

Ancient Greece
Similarly, the Greeks employed urine in their dyeing techniques. Public urinals were provided specifically to collect urine for industrial purposes, reflecting its widespread use in textile production.

Roman fullers - Mosaic in the National Archaelogical Museum in Neaples (IT) showing fullers at work

Woad Dyeing in Medieval Europe
In medieval Europe, particularly in regions such as Scotland, urine was essential for dyeing with woad—a plant used to produce a blue dye. The process involved soaking woad leaves in human urine to facilitate fermentation, which was necessary to extract the indigo pigment. Urine from individuals who had consumed alcohol was particularly valued due to its higher ammonia content.

Scientific Insights into Historical Practices

Fermentation in Urine
Stored urine undergoes fermentation as urea breaks down, releasing ammonia gas. Fermented urine contains higher concentrations of ammonia, making it more effective for dyeing processes. This explains the historical preference for stale urine in creating stronger dye solutions.

Replacement by Synthetic Ammonia
In modern times, the effects of fermented urine can be replicated using sodium carbonate or synthetic ammonia solutions, eliminating the need for fermentation. While these alternatives are more practical, exploring historical methods provides a fascinating way to understand chemical principles and the resourcefulness of ancient dyers.
By examining the historical use of urine in dyeing, we gain insight into how ancient practices laid the groundwork for modern chemistry, while also appreciating the intersection of science and culture throughout history.

Urine as a Commodity
Urine's value extended beyond its chemical properties; it was an economic asset. In ancient Rome, collectors gathered urine from public latrines to sell to fullers and tanners. The regulated trade and the imposition of Emperor Vespasian's urine tax underscore its importance in various industrial processes, including dyeing and leather tanning.

Fun Fact: Why "Liquid Gold"?
The nickname "liquid gold" originates from both its practical applications and its economic significance. The Roman system of public latrines and urine collection for industrial use exemplifies the resourcefulness of ancient societies in capitalising on this abundant resource.

Conclusion

The use of urine in textile dyeing predates the Celts, with independent practices emerging in Mesopotamia, Egypt, and Greece. Its application as a mordant and cleaning agent facilitated the creation of vibrant and lasting colours while contributing to the early industrial economies through its collection and trade. By examining this historical use, we not only uncover the scientific ingenuity of ancient civilizations but also gain an appreciation for the intersection of chemistry, culture, and economy.

Connection Between the Blue Bottle Experiment and Historical Dyeing:

The blue bottle experiment and the woad dyeing process share a common principle: **oxidation and reduction.** In both cases, colour changes result from the addition or removal of oxygen.

- **Oxidation-Reduction in Dyeing:** The woad dyeing process relies on the reduction of indigo to "indigo white" (a colourless form) and its oxidation to the blue form when exposed to air.
- **Oxidation in the Blue Bottle Experiment:** Similarly, the methylene blue indicator undergoes oxidation when oxygen is reintroduced, restoring its blue colour.

Dyeing Process Using Fermented Urine: In the traditional woad dyeing process, ammonia from fermented urine helps fix the dye onto fabric. Here's a breakdown of the chemical reactions involved:

1. **Fermentation of Urea:**
   - Urea in urine is broken down by bacteria into ammonia and carbon dioxide:(
     $(NH_2)_2CO$ (Urea) + H_2O → $2NH_3$ (Ammonia) + CO_2 (Carbon Dioxide)

2. **Reduction of Indigo:**
   - In an alkaline solution, indigo is reduced to "indigo white" (colourless), which is then absorbed by fibres:
     Indigo (blue) + Reducing Agents → Leucoindigo (colourless)

3. **Oxidation Upon Exposure to Air:**
   - When exposed to oxygen, the colourless "leucoindigo" oxidises back into the blue form, indigo:
     Leucoindigo (colourless)+O_2 → Indigo (blue)

Summary of Chemical Reactions:

- **Fermentation and Dye Fixation:** Ammonia helps fix dyes onto fabrics.
- **Reduction and Oxidation:** Indigo, when treated with reducing agents (like ammonia), becomes colourless and then oxidises back to blue, just like the blue bottle experiment.

By connecting these two processes, students can gain a deeper understanding of the roles of oxidation and reduction in both historical and modern chemistry, bringing ancient practices to life through scientific exploration.

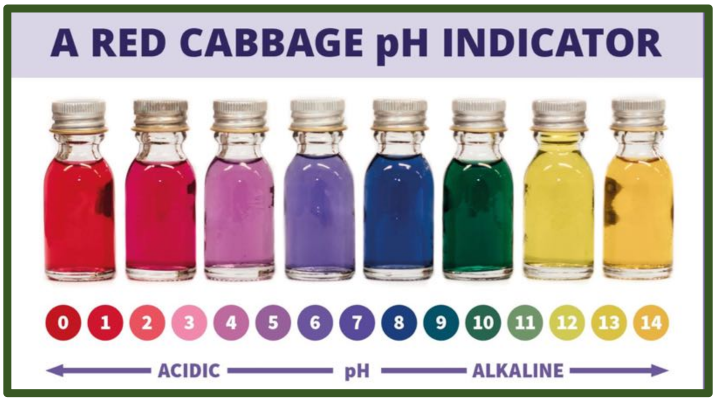
Historical Context and Fun Facts:

- Woad was not only used for dyeing but also as a trade commodity in ancient Europe, often referred to as "Celtic Blue."
- Despite the benefits, the dye had challenges. The pigment was caustic to the skin and prone to flaking, yet its cultural significance made it indispensable.
- Woad's use continued into the medieval period, and it wasn't until the 17th century that indigo, imported from overseas, replaced it as the primary source of blue dye.

The Science-History Connection:

- The story of woad provides a perfect intersection of science and history. The chemical processes of reduction and oxidation that allow the dye to change colour mirror the ancient alchemy practiced by the Celts. By blending chemistry with cultural practices, the woad dyeing process reveals how early artisans used scientific principles in their creative work.

Experiment 4: Red Cabbage Dye



Nuts and Bolts

- A red cabbage
- Saucepan
- Water *
- Sieve
- Container for the cabbage juice
- Clear plastic beakers – quantity depends on how many chemicals you are going to test.
- Paper towels!
- Gloves
- Safety glasses

Possible Chemicals to test:

- Citric acid
- Baking soda (sodium hydrogen carbonate)
- Sodium carbonate (washing soda)
- Ammonia
- Honey
- Lemon juice
- Cucumber juice
- Toothpaste

* If you live in a region with hard water, use distilled water see the handouts at the end of this section

Note substances used must not be coloured.

Crush any tablets you might want to test, then dissolve them in distilled water.

Safety

Safety glasses are to be worn

Secrets for Success

Preparing the Red Cabbage Indicator

1. Chop the red cabbage into small pieces.
2. Boil the chopped cabbage in distilled water for 10 minutes.
3. Strain the liquid, discarding the cabbage. Allow the liquid to cool.
4. Store the solution in a capped bottle and label it: **Red Cabbage Indicator – DO NOT DRINK!**

Using Red Cabbage as a Dye

Dilution for Vibrancy

Dilution can enhance the vibrancy of colour changes. Weaker dye solutions often produce more striking hues:

1. Add water to the prepared cabbage dye to create different intensities.
2. If the colours appear too light, add more concentrated dye to deepen the shade.

By experimenting with dilution, a range of beautiful and vibrant colours can be achieved.

Dyeing Fabric

1. Soak fabric pieces in the prepared cabbage dye for at least an hour, or preferably overnight.
2. Remove and dry the fabric completely on a clothesline or flat surface. Wear gloves and protect surfaces to prevent staining.
3. Once dry, rinse the fabric under running water. Observe how much of the colour remains.
4. Discuss how chemistry can help improve dye retention.

Using Alum as a Mordant

1. Prepare an alum solution in warm water (following package instructions).
2. Soak the fabric in the alum solution for about an hour, then rinse.
3. Dye the fabric again in the cabbage extract.
4. Allow it to dry completely, then rinse again. Compare how the alum-treated fabric retains more colour.

Red Cabbage Dye in Celtic Times

Though direct evidence of Celts using red cabbage for dyeing is limited, they were skilled in natural dyeing techniques, using locally available materials.

Dyeing Process

1. **Extracting the Dye**: Red cabbage leaves would be chopped and boiled in water to release anthocyanins.
2. **Adjusting the Colour**:
    - Adding acidic substances (e.g., vinegar) turns the dye **reddish-pink**.
    - Adding alkaline substances (e.g., wood ash) shifts the dye **blue-green**.

Fixing the Dye (Mordanting)

Ancient dyeing methods used natural mordants to help fix colour to fabric:

- **Alum**: A mineral that binds dye molecules to fibres.
- **Urine**: When fermented, it produces **ammonia**, which acts as a natural mordant.
- **Tannins**: Found in oak galls and certain tree barks, aiding in colour retention.

Application Process

1. Fabric was first soaked in a mordant solution.
2. It was then dyed and possibly heated to improve dye adhesion.
3. Multiple dye baths and rinsing cycles ensured deeper colour penetration.

Conclusion

Using red cabbage as a dye provides an excellent way to explore the chemistry of colour and pH while linking to historical dyeing practices. The Celts, known for their resourcefulness, likely used similar plant-based dyes and mordants to achieve a range of vibrant colours for clothing, textiles, and body art. This process demonstrates the intersection of science, art, and history, making it a fascinating topic for both learning and experimentation.

Science in a Nutshell

The Science of Red Cabbage Dye

Red cabbage contains **anthocyanins**, pigments also found in red apples, grapes, and plums. These pigments are pH-sensitive and change colour depending on acidity or alkalinity:

- **Acidic solutions** (low pH, e.g., vinegar, citric acid) turn the dye **reddish-pink**.
- **Neutral solutions** (pH 7) keep the dye **purple**.
- **Alkaline solutions** (high pH, e.g., baking soda, wood ash) shift the dye **blue-green**.

This pH-dependent colour shift makes red cabbage an excellent natural pH indicator and dye.

Acids and Bases in Chemistry

Acids release **H^+ (hydrogen) ions**, while bases release **OH^- (hydroxide) ions**. When mixed, they undergo a **neutralisation reaction**, forming water and a salt:

$$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$$

For example, **hydrochloric acid (HCl)** and **sodium hydroxide (NaOH)** react to form **sodium chloride (NaCl) and water**:

$$2HCl + NaOH \rightarrow 2NaCl + H_2O$$

Many natural dyes, like red cabbage, respond to these chemical interactions, allowing for colour modifications.

Note:
In acid-base reactions, the term **base** refers to a substance in its solid form. When a base dissolves in water, it is called an **alkali**. However, acids retain the term **acid** regardless of whether they are solid or liquid.

Chemistry Behind Dyes:

1. **Molecular Structure:**
   - Dyes are typically organic molecules that have chromophores—parts of the molecule responsible for colour—absorbing specific wavelengths of light.
   - The different functional groups within the dye can interact with the fabric based on the fabric's fibre composition (cellulose, protein, etc.).

2. **Fibre Interaction:**
   - Natural fibres (like cotton) are made up of cellulose, which has hydroxyl (–OH) groups that can form hydrogen bonds with the dye molecules.
   - Protein fibres (like wool) have amino groups that can react with dye molecules differently, often forming stronger, more defined bonds.

3. **Role of Mordants:**
   - Mordants like alum create a bridge between the dye and the fabric. They interact with both the dye and the fibre, enhancing the dye's ability to bond through ionic interactions or coordination complexes.
   - This process improves the colour-fastness of the dye, meaning the colour remains more stable and does not wash out as easily.

Summary:

In summary, the bond between dyes and fabric involves complex chemical interactions which are influenced by factors such as the type of dye, the fabric composition, and the use of mordants. Understanding these principles helps explain the differences in colour retention and vibrancy seen across different dyeing techniques. Through experimentation, such as the dyeing activity you've planned, children can observe and learn about these chemical principles in an engaging way.

HARD & SOFT WATER

The Geological Society
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BBC TERRIFIC SCIENTIFIC

This factsheet was written for primary school students aged 9-11 as part of the BBC 'Terrific Scientific' schools initiative. A factsheet for teachers and a general audience is also available on the website:

www.geolsoc.org.uk/waterhardness

Left: Soap bubbles in soft water
Right: Limescale in a kettle after boiling hard water
© Henna / Wikimedia

Have you ever noticed that tap water tastes different depending on where you are? Have you ever seen a white coating inside your kettle or the shower head, or found that the shower gel won't lather up? All these effects are caused by differences in the 'hardness' of the water.

Hard and soft water

Hard water is water that contains dissolved **minerals**. Minerals are the materials that make up rocks. Water containing less minerals (for example rainwater) is known as **soft water**. In the UK, both hard and soft tap water is safe to drink.

How does hard water form?

When rainwater falls it soaks into the ground and flows slowly down through the soil and eventually into the rocks beneath us. Some of the minerals in these rocks mix with rainwater in the same way that sugar mixes with tea, by separating into particles too small to see. This process of **dissolving** in the water forms a **solution**. Minerals which do this are called '**soluble**' minerals. Other minerals that don't dissolve are '**insoluble**'.

Cracks in the rocks grow as soluble minerals dissolve, and after many years may form caves big enough to walk around in. As the water evaporates, the newly solid minerals form beautiful shapes.
Photo: Marble Arch Caves, County Fermanagh, Northern Ireland © Robert Mulraney

Hard water: good or bad?

The good:

- Some minerals in hard water contain **calcium**, which is good for healthy bones and teeth.
- Some people think it tastes better.

The bad:

- When some hard water is boiled, the dissolved minerals become solid again and form a hard white layer called '**limescale**'. This blocks pipes and stops kettles working so well.
- Hard water forms '**soap scum**' instead of bubbles when detergent or shower gel is added. This makes washing more difficult, and uses more soap.

DID YOU KNOW?

Calcium is found in the skeletons of animals (including humans) and is essential for strong bones and teeth. When animals die, all that usually remains are their skeletons. Some rocks contain calcium minerals because they are formed from the **fossils** of ancient animals (find out how on the next page). Hard water found in these rocks often contains lots of dissolved calcium.

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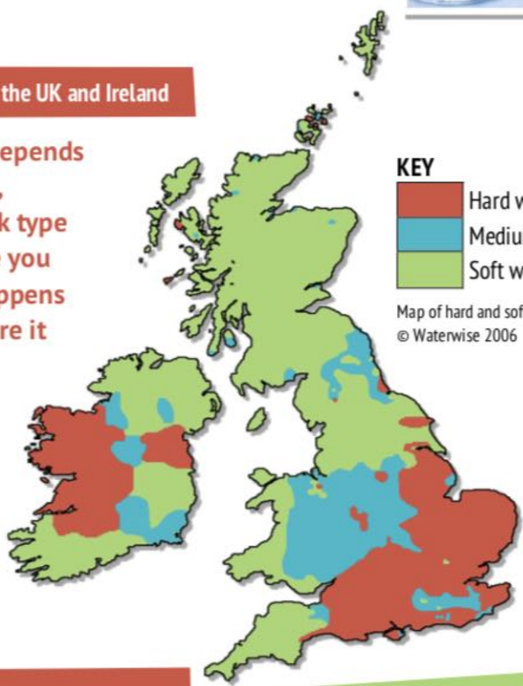
Testing for hard water

- A simple way to test your water hardness is by adding soap. The more soap needed to make bubbles the harder the water.
- You can also use test kits to measure the dissolved calcium. The map below shows how water hardness varies across the UK and Ireland.

Hard and soft water in the UK and Ireland

Water hardness depends on several things, including the rock type in the area where you live, and what happens to the water before it reaches your tap.



KEY

- Hard water areas
- Medium hard water areas
- Soft water areas

Map of hard and soft water areas
© Waterwise 2006

Hard water areas

In much of England and Ireland, tap water is pumped out of underground **aquifers** (rocks storing water in cracks and gaps). This is known as '**groundwater**'.

The rocks in some areas are **chalk** (south east England) and **limestone** (Yorkshire), which are made up of soluble minerals. The water is soft when it falls as rain, but often stays underground for long enough for minerals to dissolve from the chalk or limestone, forming hard water.

Soft water areas

In other areas, such as much of Scotland and Wales, most of our drinking water comes from rivers, lakes and reservoirs. This is known as '**surface water**'. This water is **soft** because it has not been in contact with rocks for long enough for the minerals to dissolve.

Some rock types are **less soluble**, so even where drinking water comes from groundwater it may be softer because less minerals have dissolved. For example, the groundwater is often softer in areas such as Nottingham where the main rock is **sandstone**, which is made up of less soluble mineral grains.

Chalk, limestone and fossils

Hard water areas get groundwater from chalk or limestone rocks.

- **Chalk** is the white rock that forms the 'white cliffs of Dover'. It is soft and can be used to draw on a blackboard.
- **Limestone** is a harder grey rock which can form spectacular caves, some of which are open for the public to explore.

Chalk cliffs at Seven Sisters, Dover, UK

Both these rocks are made of soluble **calcium** minerals, which formed millions of years ago from the skeletons of sea animals. After the animals died they sank to the seabed and the soft parts of their bodies rotted away. Their hard skeletons were buried and eventually turned into **fossils**.

Fossil Ichthyosaur (marine reptile) skull found on the Jurassic Coast, UK

Why was part of the UK underwater?

Millions of years ago, the Earth's climate was warmer than it is today. Ice at the north and south poles had melted, so the sea level was higher. Chalk and limestone formed when parts of the UK were at the bottom of a shallow sea that covered much of Europe!

Sometimes it's not that simple!
Why you might get unexpected results if you test your water...

The water in your tap could have come from underground water nearby, or a reservoir further away. So even if you live in a 'hard water area', your water might be softer than you expect. One example is Birmingham, where water comes from reservoirs in Wales!

Experiment 5: Brewing Willow Bark Tea –- A Celtic Remedy

Safety Note: Do not consume anything from the wild that a professional has not verified or accurately identified. Always ensure correct identification before harvesting and consuming any plant. Some plants can be toxic if misidentified. Check local regulations and forage sustainably.

Introduction

The Celts, like many ancient civilisations, relied on nature for medicine. One of their most powerful remedies came from willow bark (*Salix* species), which contains **salicin**—a compound that acts similarly to modern aspirin. Historical records and archaeological evidence suggest that ancient peoples, including the Celts, used willow bark to treat **fevers, headaches, and other pains**, much like we use aspirin today. This experiment will demonstrate how to extract salicin from willow bark by brewing tea.

Nuts & Bolts

- Dried or freshly harvested willow bark (2 teaspoons per cup of water)
- A sharp knife or potato peeler (for bark preparation)
- A saucepan or heatproof container
- Boiling water (1 cup per serving)
- Tea strainer or muslin cloth
- Optional: 2 teaspoons of cinnamon, ½ teaspoon of honey, a pinch of turmeric
- Heat source (e.g., stove, hot plate, or open fire)
- Timer or stopwatch

Secrets for Success

1. **Harvesting the Bark** (If using fresh willow):
    - Identify a willow tree (*Salix* species), preferably near a water source.
    - Select young, flexible branches and cut them at a node to allow regrowth.
    - Use a knife or potato peeler to strip down to the inner bark.
    - Allow the bark to dry or use fresh.
2. **Preparing the Tea:**
    - Measure out **2 teaspoons of willow bark per cup of water**.
    - Place the bark into a **saucepan** or **heatproof container**.
    - Add boiling water and simmer for **10 minutes**.
    - Remove from heat and allow to steep for **30 minutes** to extract the active compounds.
    - Strain out the bark using a tea strainer or muslin cloth.
3. **Enhancing the Brew:** (Optional)
    - **Cinnamon**: Contains anti-inflammatory properties and adds flavour.

- **Turmeric**: Rich in curcumin, which supports joint and digestive health.
- **Honey**: Has antibacterial properties and soothes sore throats.

4. **Serving and Warnings:**
    - Drink warm for pain relief and overall well-being.
    - **Do not consume if pregnant, breastfeeding, taking blood thinners, or if you have gastrointestinal issues.**
    - **Children should not consume willow tea.**
    - Drinking a litre of tea provides the equivalent of a few aspirin tablets.

Science in a Nutshell

- **Salicin → Salicylic Acid:** Once ingested, salicin is converted by the body into **salicylic acid**, which reduces inflammation and pain. This is the natural precursor to modern aspirin.
- **Boiling and steeping:** Heat helps extract salicin and other beneficial compounds from the bark.
- **Honey's Medicinal Role:** Honey contains natural antibacterial properties and can soothe irritation, making it a useful addition to herbal remedies.

Celtic Knowledge of Medicinal Plants

The Celts, like many ancient societies, relied on nature for medicine. Druids and healers were known to have a deep understanding of the medicinal uses of plants. While direct written records from the Celts themselves are scarce (much of what we know comes from Roman and Greek accounts), archaeology and ethnobotany suggest a rich tradition of herbal medicine.

Medicinal Plants Known to the Celts

Here are some plants the Celts likely used for medicinal purposes:

1. **Willow (*Salix spp.*):** Used for pain relief and to reduce fever.
2. **Yarrow (*Achillea millefolium*):** Used for wound healing and stopping bleeding. Its astringent properties made it effective in treating cuts.
3. **Elder (*Sambucus nigra*):** The flowers and berries were used to treat colds, fevers, and respiratory issues.
4. **Mugwort (*Artemisia vulgaris*):** Used as a digestive aid, for menstrual issues, and to repel insects.
5. **Meadowsweet (*Filipendula ulmaria*):** Contains salicylates, like willow, and was used to treat pain, fevers, and stomach ailments.
6. **Foxglove (*Digitalis purpurea*):** While toxic, small doses may have been used for heart-related conditions (though this is speculative, as it requires precise knowledge to avoid poisoning).
7. **Nettle (*Urtica dioica*):** Used for joint pain, as a diuretic, and to stimulate circulation.
8. **Heather (*Calluna vulgaris*):** Used for urinary tract issues and as an antiseptic.
9. **Valerian (*Valeriana officinalis*):** Used as a sedative and to treat insomnia and anxiety.
10. **Woad (*Isatis tinctoria*):** Beyond its dyeing properties, woad leaves may have been used for antiseptic purposes on wounds.

Medicinal Practices

The Celts combined their knowledge of plants with rituals and spiritual practices. Healing was likely holistic, addressing the physical and spiritual needs of the patient. Herbal infusions, poultices, and salves were commonly prepared. Plants were often harvested with respect for the natural world, sometimes accompanied by rituals to honour the plant's spirit or ensure its efficacy.

Celtic Use of Urine in Medicine

In Celtic times, urine was considered a valuable resource. Its high ammonia content made it useful for:

1. Cleaner: A Smelly but Effective Secret!
Long before fancy detergents, people had to get creative with their laundry—using **wee-wee!** Yes, really! **Urine contains ammonia**, a natural cleaning agent that breaks down grease and stains, making it an unexpectedly useful washing tool.

In ancient times, laundry day wasn't exactly a fresh and floral experience. Imagine this: instead of popping clothes into a washing machine, people collected urine in special pots placed around the streets. Once full, these pots—called **vats**—were taken to the local laundry, known as a **fullonica**.

Here's where it gets even stranger… **workers would pour the urine over dirty clothes, mix it with water, and then stomp on them with their bare feet!** This was their version of a washing machine's agitator, except instead of spinning with electricity, it was powered by smelly human feet!

It might sound disgusting, but it worked! **Would you have taken that job?**

---

2. Whitener and Brightener (Pee Power!)
Ammonia doesn't just clean—it also whitens. It was used to brighten fabrics like wool and linen. This was especially useful for keeping white clothes looking fresh.
"Want your clothes to sparkle at the next Celtic party? Dip it in some...you guessed it...wee-wee!"

---

3. Fabric Softener (Cuddle Up with Pee!)
Before we had fabric softeners, urine was sometimes used to soften animal hides and cloth. The urea in urine breaks down fibres, making them easier to work with.
"If you thought snuggling a blanket was comfy, imagine knowing it was softened with… uh… no, let's not imagine that."

---

3. Wound Cleaning
Urine has mild antiseptic properties and was sometimes used for wound treatment. While modern science does not recommend urine for medicinal use, its historical applications provide insight into the resourcefulness of ancient societies.

Conclusion:

This experiment connects chemistry, history, and medicine by demonstrating how ancient Celtic remedies were grounded in science. Willow bark tea was an early form of pain relief, and the Celts' use of natural resources, such as honey and even urine, showcases their innovative approach to health and hygiene.

Further Exploration: Try experimenting with different steeping times and ingredients to observe variations in taste and effectiveness!

Experiment 6: Soap Making Activities

Introduction
In these activities, children will make their own soap while learning about basic chemical processes such as melting, mixing, evaporation, and phase changes. This section includes several soap-making projects alongside science experiments that explain the 'why' behind the process. Remember, adult supervision is essential, especially when dealing with hot materials.

Soap Making Activities

1. Melt-and-Pour Soap Making

What You Need:

- A melt-and-pour soap base (choose either clear or white)
- Microwave-safe bowls or a double boiler
- Soap colourants (such as food colouring or soap-specific dyes)
- Fragrance oils (ensure these are skin-safe)
- Fun soap moulds (silicone moulds in shapes like animals, stars, or letters)
- Stirring sticks and spoons

Activity Steps:

1. **Melt the Soap Base:**
   Cut the soap base into small cubes. With adult supervision, melt the cubes in the microwave (using short bursts of 15 seconds – don't over heat the soap as it will spoil the end product) or in a double boiler until they are fully liquid.
2. **Personalise the Mixture:**
   Divide the melted soap into several small bowls. Allow each child to add a few drops of colourant and a tiny amount of fragrance. Stir gently to mix.
3. **Pour into Moulds:**
   Carefully spoon or pour the coloured soap into the chosen moulds.
4. **Set and Unmould:**
   Allow the soap to cool and harden for about 1–2 hours. Once set, pop the soap out and, if desired, decorate further with markers or stickers.

Learning Points:

- Understanding basic chemistry (melting, cooling, and solidifying)
- Exercising creativity with colours and scents
- Following step-by-step instructions

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2. Layered or Swirled Soap

What You Need:

- A clear melt-and-pour soap base
- Different food-safe colourants
- Silicone moulds

- Straws (to create swirled patterns)

Activity Steps:

1. **Prepare the Layers:**
   Melt the soap base and divide it into two or more portions. Add different colours to each portion.
2. **Layer the Colours:**
   Pour a layer of one colour into a mould. Allow it to set slightly (enough so that the next layer won't mix completely).
3. **Add Additional Layers:**
   Pour another coloured layer on top of the first.
4. **Create Swirls:**
   Before the soap fully sets, gently swirl the layers together using a straw to create a marbled effect.

Learning Points:

- Understanding the principles of layering and mixing
- Experimenting with colour combinations
- Observing how different liquids interact

3. Nature-Inspired Soap

What You Need:

- Melt-and-pour soap base
- Natural additives (such as dried flower petals, oats, or a few drops of essential oil like lavender for a calming scent)
- Child-friendly, safe moulds

Activity Steps:

1. **Melt and Mix:**
   Melt the soap base and mix in natural additives.
2. **Personalise with Nature:**
   Allow each child to choose their favourite additive (after checking for allergies) and mix it into their soap.
3. **Pour and Set:**
   Pour the mixture into moulds and let it set until hardened.

Learning Points:

- Exploring natural ingredients and their properties
- Gaining a sensory experience with different textures and scents
- Learning the importance of safety and hygiene when making everyday items

4. Soap Painting

What You Need:

- Pre-made plain soap bars (unscented and uncoloured)
- Food colouring diluted in a little water
- Paintbrushes

Activity Steps:

1. **Prepare the 'Paint':**
   Mix food colouring with a small amount of water to create liquid paints.
2. **Decorate the Soap:**
   Let the children paint designs on the soap bars. As the water evaporates, the colours will set, making their artwork permanent.
3. **Dry and Use:**
   Once the soap is dry, the painted design is fixed, and the soap is ready for use.

Learning Points:

- Combining art with a practical craft
- Understanding how colours change with dilution and drying
- Developing fine motor skills through painting

---

5. Glycerine as a Humectant

Objective:
Demonstrate how glycerine attracts water from the air.
Materials:

- Glycerine
- Two plates or petri dishes
- A humid environment or a small bowl of water nearby

Steps:

1. Pour a small puddle of glycerine onto one plate and leave the second plate empty as a control.
2. After 5–10 minutes, observe both plates. The glycerine puddle will appear larger or shinier as it absorbs moisture from the air.

Science Link:
Glycerine acts as a humectant, drawing water from the air to keep skin moisturised. This property makes it a valuable ingredient in soap to help maintain skin hydration.

---

6. Essential Oils and Evaporation

Objective:
Illustrate why we can smell essential oils.
Materials:

- A few drops of essential oil
- Warm water
- Cotton pad or blotting paper

Steps:

1. Place a drop of essential oil on a cotton pad and smell it.
2. Dip the cotton pad briefly in warm water, then smell it again. The scent should intensify as the heat speeds up evaporation.

Science Link:
Essential oils are volatile, meaning their molecules easily evaporate into the air. This evaporation carries the fragrance to our noses, allowing us to enjoy the scent.

---

7. Colour Mixing with Pigments

Objective:
Explore how colours mix in liquids.

Materials:
- Two clear cups of melted soap base (or water)
- Soap-safe liquid dyes (primary colours: red, yellow, blue)
- Stirring sticks

Steps:
1. Add one colour to each cup of melted soap or water.
2. Slowly pour one into the other, stirring gently to observe how the colours mix to form a new shade.

Science Link:
The dyes create a suspension, where tiny pigment particles distribute evenly throughout the liquid. This demonstrates the principles of colour mixing and dispersion.

---

8. Floating or Sinking Exfoliants

Objective:
Examine how density affects the behaviour of exfoliants in soap.

Materials:
- A glass of melted soap base (or water)
- Various exfoliants (e.g., oatmeal, poppy seeds, coffee grounds)

Steps:
1. Drop a pinch of each exfoliant into the melted soap or water.
2. Observe which materials float, sink, or remain suspended.

Science Link:
The behaviour of the exfoliants depends on their density relative to the soap base. This experiment provides insight into how density and timing of mixing can control where additives settle.

---

9. Surface Tension with Bubbles

Objective:
Use glycerine to stabilise bubbles and explore the concept of surface tension.

Materials:
- Dish soap
- Glycerine
- Water
- A bubble wand or straw

Steps:
1. Mix 1 part dish soap, 1 part glycerine, and 6 parts water.
2. Blow bubbles and observe how they last longer and are more resilient compared to bubbles made with dish soap alone.

Science Link:
Bubbles form because of surface tension—the cohesive force between liquid molecules. Glycerine helps slow down the evaporation of water, strengthening the bubble film and allowing the bubbles to last longer.

10. Exploring Melting Points

Objective:
Highlight the importance of melting points in soap making.
Materials:

- SLS-free melt-and-pour soap base (cut into small pieces)
- A thermometer
- A microwave or double boiler
- A heat-resistant container

Steps:

1. Place small pieces of the soap base in a heat-resistant container.
2. Gently heat the soap base in a microwave (in short intervals) or over a double boiler while monitoring the temperature with a thermometer.
3. Note the temperature at which the soap begins to melt and becomes fully liquid.
4. Allow the soap to cool and observe at what temperature it starts to solidify.

Science Link:
Every substance has a specific melting point—the temperature at which it transitions from a solid to a liquid. Understanding the melting point of the soap base ensures that it is heated just enough to melt without overheating, which could degrade sensitive ingredients like essential oils. This experiment ties directly into the principles of phase changes in chemistry.

Tips for a Successful Activity

- **Supervision and Safety:**
  Always ensure an adult is present to manage hot materials and equipment.
- **Allergy Check:**
  Confirm that all additives (such as essential oils and natural ingredients) are safe and do not cause allergic reactions in the children.
- **Clean Workspace:**
  Cover surfaces with newspapers or a plastic sheet to simplify clean up.
- **Discussion:**
  Use these activities as an opportunity to discuss the science behind melting, mixing, and setting, making the experience both educational and fun.

By combining these creative soap-making activities with engaging science experiments, children not only have the chance to craft their own unique soap but also gain a practical introduction to fundamental scientific concepts. Enjoy your session and have fun bringing science to life!

From ember to Explosion: The science of grain dust hazards

The Chemistry and the Celts Show ends with the roof of the grain house lifting skywards, this is a dramatic visual of how an explosion can occur when a burning ember is carried into a grain shed by a gust of wind.

This incident underscores a crucial safety concern in agricultural practices, particularly in the handling of grain dust, which can be highly explosive. Our model of a round house experienced a simulated roof explosion, highlighting the potential hazards associated with this overlooked aspect of grain storage.

Understanding the science behind such phenomena is essential for improving safety measures in grain facilities.

Scientific Explanation of the Fire Triangle

To comprehend why grain dust poses such a significant hazard, we can refer to the fire triangle, which consists of three essential elements required for combustion: fuel, heat, and oxygen.

1. **Fuel**: In this case, the fuel is the grain dust itself, which comprises tiny particles that can ignite easily when suspended in the air.
2. **Heat**: The burning ember serves as the heat source. If the temperature of the ignition source is high enough, it can ignite the dust particles.
3. **Oxygen**: Grain dust particles must be in an environment where sufficient oxygen is present. When dust is airborne, it maximizes its surface area and likelihood of coming into contact with oxygen.

When all three elements of the fire triangle are present, a rapid combustion reaction can occur, leading to an explosion.

Historical Examples of Grain and Flour Dust Explosions

Grain and flour dust explosions have been documented throughout history, causing significant damage and loss of life. Here are a few notable examples:

1. **The 1878 Minneapolis Flour Mill Explosion**: One of the most catastrophic incidents occurred when a flour mill explosion in Minneapolis killed 18 people and injured many more. The combination of fine flour dust and an ignition source led to a massive explosion and the destruction of the mill.
2. **The 1928 Oppau Explosion**: This series of explosions in Germany occurred when a mixture of ammonium sulphate and ammonium nitrate stored in large silos ignited. The resulting blast was catastrophic, levelling the facility and claiming over 500 lives. Although primarily a chemical explosion, the explosion of the dust clouds contributed to its severity.
3. **The 1908 Dublin Flour Mill Explosion**: In Dublin, a flour mill explosion occurred due to flour dust igniting, which caused significant damage to the mill and highlighted the dangers inherent in flour storage and processing.
4. **The 1921 County Tipperary Explosion**: Reports indicate that a grain silo explosion caused considerable destruction in a Tipperary grain store, though detailed records may be scarce. The incident served as a stark reminder of the potential hazards of storing combustible dust.
5. **The 1971 Runcorn Explosion**: The explosion of a corn mill in Runcorn, England, resulted from the ignition of flour dust and led to multiple fatalities and injuries. It illustrated the dangers associated with grain and flour dust in milling operations.

6. **The 2008 Explosion at the Imperial Sugar Refinery**: In Port Wentworth, Georgia, a sugar dust explosion claimed the lives of 14 workers and injured dozens. The incident was attributed to an ignition source coming into contact with an accumulation of sugar dust, highlighting the risk in industries dealing with fine particulate solids.

These examples reveal the importance of understanding the fire triangle and implementing proper safety protocols to mitigate the risks associated with combustible dust in agricultural and industrial settings. Continuous education and adherence to safety standards can help prevent future tragedies stemming from such explosive hazards.

Curriculum Links

Experiment 1: Extraction of Iron from Iron Oxide

Primary Curriculum (Key Stages 1 & 2)

- **Materials and Their Properties** – Understanding different materials, including metals like iron, and exploring properties such as magnetism and separation techniques.
- **Forces and Magnets** – Investigating magnetic attraction and repulsion, with iron's magnetic properties linking to practical explorations.
- **Changes in Materials** – Foundational knowledge on heating and cooling processes, relevant to extraction.

Secondary Curriculum (Key Stage 3 & GCSE)

- **Reactivity Series and Metal Extraction (KS3)** – Exploring metal extraction, including reduction of iron oxide with carbon, displacement reactions, and redox chemistry.
- **Forces and Electromagnetism (KS3)** – Understanding iron's role in electromagnets and its real-world applications.
- **GCSE Science (KS4)** – Topics include the reactivity series, blast furnaces, and chemical equations in metal extraction. Magnetic properties of iron are also explored in contexts such as transformers and electric motors.

Resources and Teaching Examples

- Practical experiments on the magnetic properties of iron using magnets and iron filings.
- Historical and technological significance of iron extraction through blast furnaces.

Experiment 2: Celtic Face Painting Activity – Inspired by Woad

Primary Curriculum (Key Stages 1 & 2)

- **Science (Chemistry)** – Understanding materials and natural pigments, exploring changes in state (e.g., liquid paint drying to a solid).
- **Art and Design** – Colour mixing and experimenting with primary and secondary colours.
- **History/Geography** – Cultural significance of natural dyes and how ancient societies, such as the Celts, used natural resources in art and celebrations.

Secondary Curriculum (Key Stage 3 & GCSE)

- **Science (Chemistry)** – Investigating oxidation and reduction in pigment formation, and how pH affects natural dyes.
- **Art and Design** – Analysis of pigments in historical art, interdisciplinary projects on natural dye-making.
- **Environmental Science** – Sustainability of natural pigments compared to synthetic dyes.

- **History** – The role of woad and other natural pigments in historical art movements and cultural traditions.

Resources and Teaching Examples

- Practical activities exploring woad dyeing, including chemical reactions and artistic applications.

Experiment 3: Blue Bottle Experiment

Primary Curriculum (Key Stage 2, Years 5–7)

- **Change Over Time** – Investigating irreversible changes in materials and recognising energy changes in chemical reactions.
- **Thinking Skills & Personal Capabilities** – Conducting scientific investigations, observing colour changes, and developing problem-solving skills.

Secondary Curriculum (Key Stage 3 & GCSE)

- **Chemical Reactions and Materials (KS3)** – Understanding oxidation as the gain of oxygen or loss of electrons, and reduction as the opposite. Investigating how methylene blue acts as an electron carrier.
- **GCSE Chemistry (CCEA)** – Exploring oxidation and reduction reactions, electron transfer, and the role of indicators such as methylene blue.

A-Level Chemistry (CCEA)

- **Redox Chemistry** – Defining oxidation and reduction in terms of electron transfer and investigating oxygen's role in oxidation.

Resources and Teaching Examples

- A visually engaging experiment to introduce redox chemistry with real-time colour changes.

Experiment 4: Red Cabbage Dye

Primary Curriculum (Key Stages 1 & 2)

- **Science (Chemistry Basics)** – Understanding solutions, solubility, acids, and bases.
- **History** – Exploration of historical dyeing techniques and their cultural significance.
- **Art and Design** – Hands-on textile projects using natural dyes.

Secondary Curriculum (Key Stage 3 & GCSE)

- **Chemistry** – Investigating oxidation and reduction, pH indicators, and the chemistry of natural dyes.
- **Physics** – Examining how light absorption and reflection influence colour changes.

- **History** – The impact of the Industrial Revolution on dyeing techniques and their societal influence.
- **Biology** – Studying plant extracts and their practical uses in textiles.
- **Art and Design** – Designing and dyeing fabrics using traditional methods.

Resources and Teaching Examples

- Cross-curricular learning by combining science, history, and art through hands-on dyeing activities.

Experiment 5: Brewing Willow Bark Tea – A Celtic Remedy

Primary Curriculum (Key Stages 1 & 2)

The World Around Us (Science & Technology)
- Investigate the importance of plants in everyday life.
- Explore how materials change when mixed, heated, or cooled (link to extracting salicylic acid from willow bark).

Personal Development & Mutual Understanding
- Understand how medicines are used to treat illnesses (early introduction to pharmaceuticals).

Secondary Curriculum (Key Stages 3 & 4)

KS3 Science
Biology: Health and the Human Body
- The role of drugs and medicines in health.
- The development of modern medicine (historical context of aspirin).

Chemistry: Materials and Their Properties
- Investigate the properties of substances (solubility, acids, alkalis).
- Learn about changes of state and chemical changes (extraction process).

GCSE Science (CCEA – Key Stage 4)
Biology: Health, Disease & Medicine Development
- The discovery and development of medicines, including traditional remedies.
- The role of plants in drug development.

Chemistry: Organic Chemistry
- The structure and function of organic compounds (salicylic acid, aspirin).
- Chemical reactions used in the production of pharmaceuticals.

Cross-Curricular Links
This topic also connects with:

- **History**: The development of medicine (Hippocrates, traditional remedies, modern pharmaceuticals).
- **PSHE (Personal, Social, Health & Economic Education)**: The role of medicines in society.
- **Geography**: The sourcing of natural medicines from plants around the world.

Experiment 6: Soap Making

Primary Curriculum (Key Stages 1 & 2)

- **Science (States of Matter and Changes of State)** – Exploring how soap melts and solidifies, linking to materials changing state.
- **Properties of Materials** – Investigating texture, flexibility, and the effects of natural additives.
- **Working Scientifically** – Observing and predicting outcomes, discussing observations of colour and texture changes.
- **Everyday Chemistry** – Exploring simple chemical processes such as dissolving and colour mixing.
- **Design and Technology**
    - **Creative Design and Making** – Planning and designing personalised soap bars, encouraging problem-solving and creativity.
    - **Understanding Materials** – Learning about natural additives and essential oils in product design.

Secondary Curriculum (Key Stage 3 & GCSE)

- **Chemistry**
    - **Phase Changes and Thermal Properties** – Investigating melting points and phase transitions.
    - **Mixtures and Solutions** – Exploring suspensions, solutions, and molecular dispersion.
    - **Organic Chemistry and Surfactants** – Understanding the role of surfactants in cleaning and the chemistry of soap.
    - **Chemical Reactions and Safety** – Introducing exothermic and endothermic reactions, along with chemical safety.
- **Physics**
    - **Thermal Energy and Heat Transfer** – Observing how heat affects melting and solidification.
    - **Density and Buoyancy** – Investigating floating and sinking exfoliants.
    - **Surface Tension** – Linking bubble formation to intermolecular forces.
- **Design and Technology**
    - **Product Design and Innovation** – Exploring material selection, sustainable ingredients, and ethical product development.

Resources and Teaching Examples

- Engaging hands-on activities combining chemistry, product design, and sustainability discussions.

Concluding Demonstration: The Grain Store Explosion

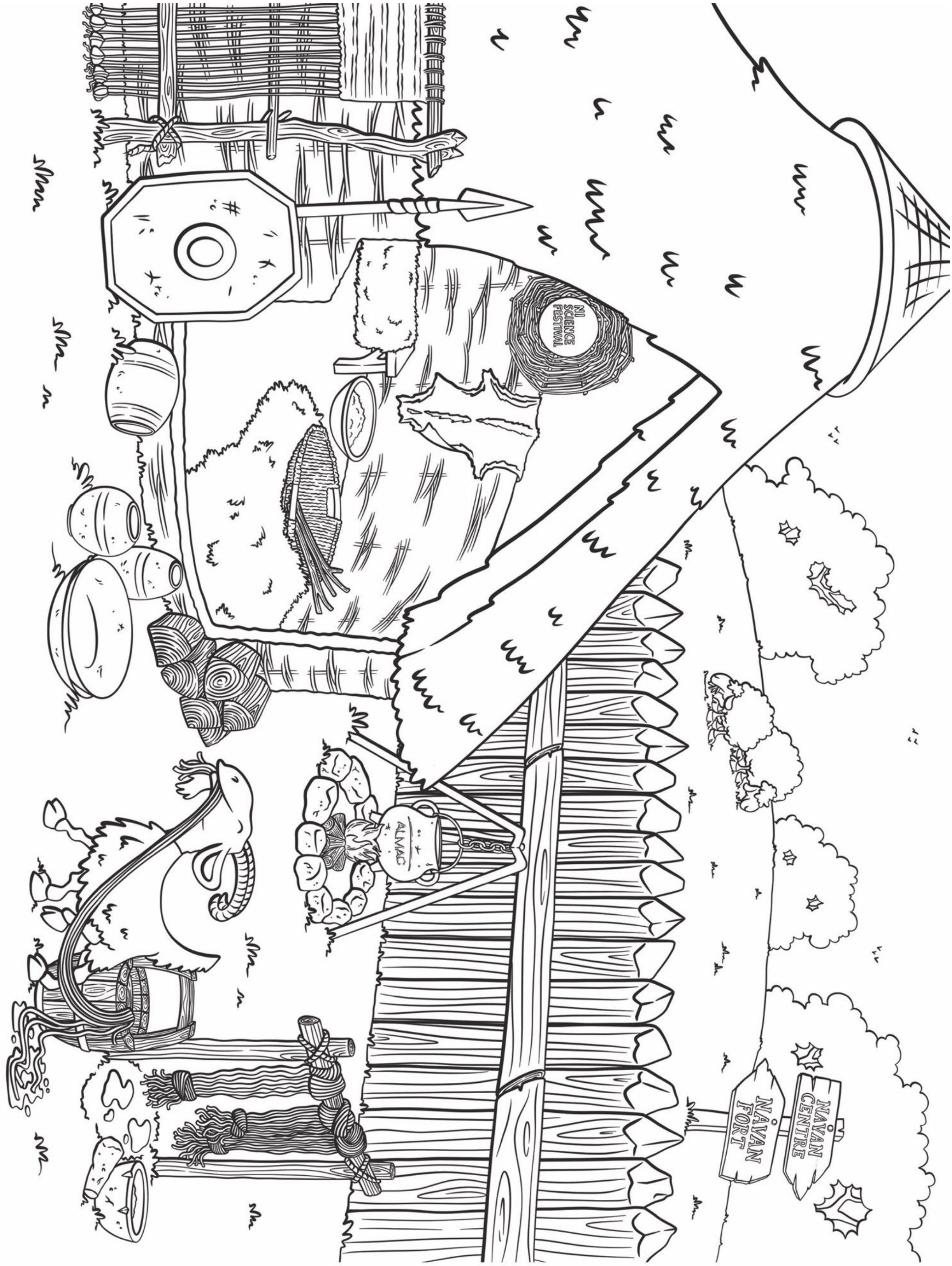
Primary Curriculum Links

1. **The World Around Us (WAU)**:
   Understanding the World: Explore changes in the environment, including those caused by human activities such as storage and processing of grains.
   - **The Nature of Science**: Investigate materials, their properties, and how they react, fostering an understanding of fire, explosions, and safety.
2. **Science and Technology**:
   - **Scientific and Technological Understanding**: Learn about the basic principles of heat, light, and sound, including combustion and the causes of fire.
   - **Working Scientifically**: Develop skills in making predictions, carrying out experiments, and understanding scientific concepts like the fire triangle.
3. **Personal Development and Mutual Understanding**:
   - **Health and Safety**: Discuss the importance of safety measures in everyday life, including fire safety at home and in the community.

Secondary Curriculum Links

1. **Science**:
   - **Key Stage 3 & 4**: Explore the principles of energy, combustion, and the chemical reactions that occur during burning processes, including the fire triangle.
   - **Practical Skills**: Design and conduct experiments related to combustion and related hazards, fostering understanding of safety protocols.
2. **Technology and Design**:
   - **Problem-Solving**: Investigate how to minimize risks in industrial settings, including safe storage of materials such as grain to prevent explosions.
3. **Geography**:
   - **Human Interaction with the Environment**: Examine case studies of industrial accidents and their impacts on communities, emphasizing the need for safety and risk management.
4. **Learning for Life and Work**:
   - **Safety Awareness**: Discuss the role of safety regulations in various industries and the impact of hazardous materials on health and safety.

These curriculum links align with the key concepts of safety, science, and awareness of environmental hazards present in your demonstration. You can integrate these ideas into lesson plans to create engaging discussions and educational activities for both primary and secondary students.



NI Science Festival - Chemistry & the Celts

Thank You!

The NI Science Festival team and myself would like to extend our heartfelt gratitude to you for attending the show and our key sponsors, **Almac Group, Arts & Business NI,** and the **Navan Centre and Fort**, for their invaluable support in making the "Chemistry and the Celts" show a reality for this year's NI Science Festival. Your commitment to promoting science and culture in our community is truly appreciated.

To all schools and event organisers, we are excited to announce that starting from **1st March**, you can book the "Chemistry and the Celts" show for your own events. We look forward to bringing this engaging experience to your students and audiences!

For those who have already enjoyed the show, we would love to hear from you! Please share your experiences and photos on social media. Your feedback helps us grow and inspires others to join in the fun.

Connect with us on social media:

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Thank you for being a part of this exciting journey!

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