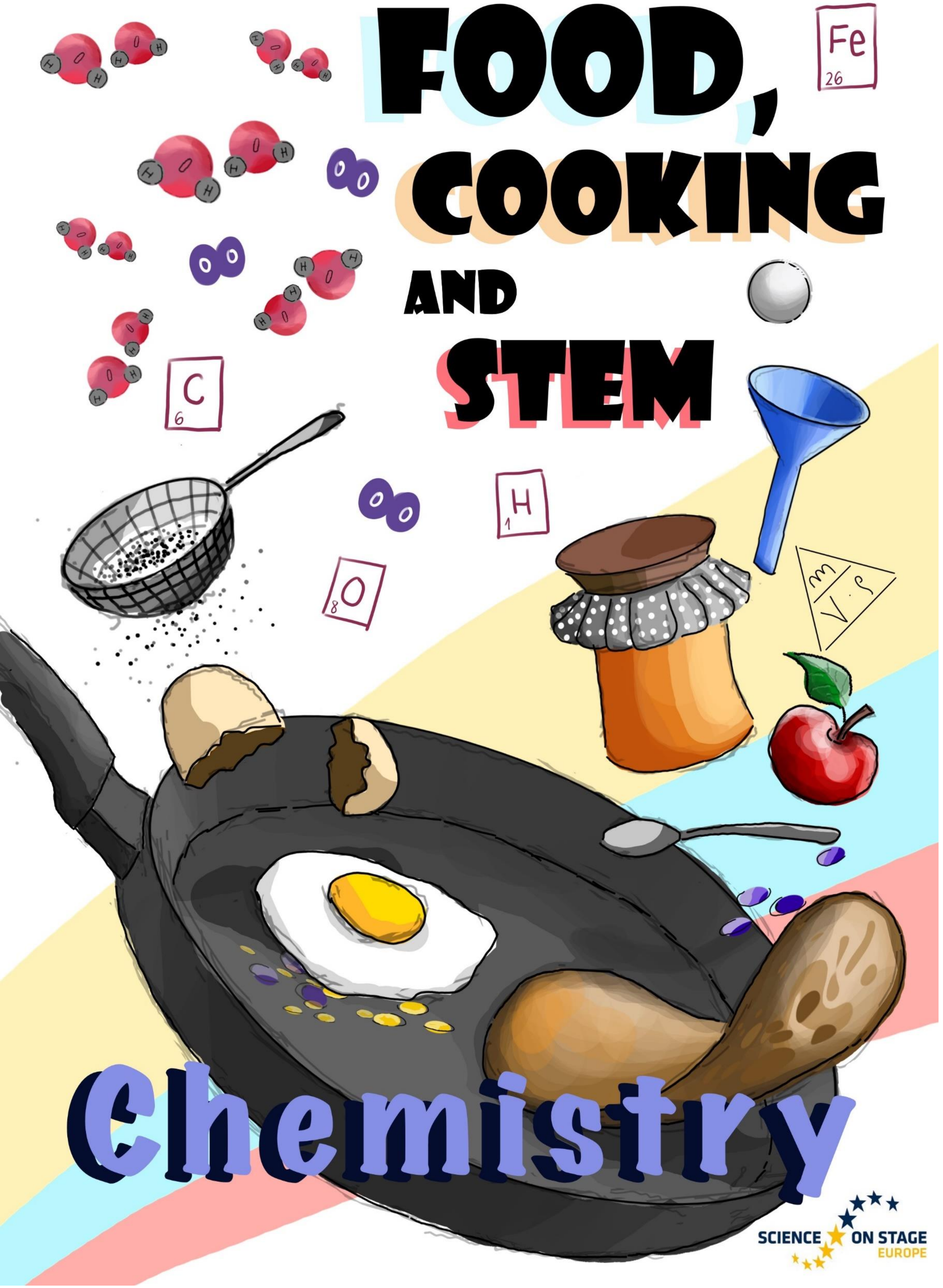
FOOD, COOKING AND STEM



Chemistry

SCIENCE ON STAGE EUROPE

Science on Stage Europe

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About us

Science on Stage Europe brings together science teachers from across Europe to exchange best practice and teaching ideas and concepts with passionate colleagues from over 30 countries. Science on Stage Europe believes that the best way to improve science teaching and to encourage more schoolchildren to consider a career in science or engineering is to motivate and inform their teachers. The non-profit organisation was founded in 2000 and reaches 100,000 teachers Europe-wide.

Credits

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Cover illustration by Kristina Dovalova and Gabriela Coelho

Content

Suited to all ages and accessible to primary children.

Particular targeted at secondary

⚠ Health and Safety

All experiments should be performed with due diligence taking into consideration the children concerned and whether they need direct supervision, or whether the experiment is only suitable for demonstration, and conforming to the safety regulations of your own country.

Foreword

FOOD and COOKING and STEM is the product of a brainstorming session at the Science on Stage Festival in Prague in March 2022, when 15 or so teachers from over Europe decided that sharing our ideas using everyday items would be useful.

Over the next year or so we will produce a series of experimental sheets giving introductions to different areas of the science curriculum, using everyday "food" items. We have divided our posts into several sections so that each one will contain some material suitable to all stages of school education and STEM subjects.

This section covers some simple experiments about the "chemistry in cooking and in food items".

Thank you for downloading this … we hope you find some inspiration in the following pages…and maybe add some ideas of your own.

Red Cabbage and Fried Eggs

Using Red cabbage as an indicator

Science: Colour changes of red cabbage liquid

FOOD, COOKING AND STEM

Age Range
Primary /Secondary

Science Principle
Red Cabbage as an indicator and the changing pH of eggs

Equipment/Material Needed
- Red cabbage
- Stove
- Pot, pan
- Egg

Description
Prepare solution of red cabbage by boiling some cut up leaves. This is the indicator solution. Red cabbage solution ranges from acid at pH 2 through neutral at pH 7 to alkali at pH 10/12

Red Cabbage Indicator

pH	2	4	6	8	10	12	14
Color							

ACID ALKALI

For the experiment get ready to "fry" and egg in a pan. (Various aged eggs from newly laid onwards may be used). Break the egg into the pan and before the albumen begins to turn from clear to opaque white drip some of the solution onto it as it cooks.

Look carefully at any colour changes and link them with the above table.

Preparing the red cabbage liquid and cracking an egg into the frying pan. Note clear al-

Conclusion/Result
The "white "part of the egg turns green, indicating that the "white" is alkaline. The newest eggs only show a slight tendency towards green, but as the eggs get older, the "white" becomes more alkaline until a fairly clear green is visible.

The second picture shows two eggs, the one on the left has had lemon juice (acid) added whilst the other on is just as it came out of the shell (both have cabbage liquid added).

NOTE: The older the egg the more alkaline the white becomes due to the changes that take place. The carbon dioxide in the egg is in the form of carbonic acid when it is dissolved in the yolk and white. In time the carbon dioxide is slowly lost through the pores in the shell. The yolk rises from a slightly acidic pH of 6.0 to a nearly neutral 6.6 while the albumen (white) goes from a somewhat alkaline 7.7 to a very alkaline 9.2.

The other change in the white as it becomes more alkaline is that it changes from thick slightly cloudy to clear, which is because the proteins in the albumen initially cluster together in masses large enough to deflect light rays, but in more alkali conditions those proteins repel each other, and the white gets more and more runny.

Top Tips: Obviously, care must be taken when cooking over a flame.

Internet links: There are many “red cabbage “ experiments to be found online.

Contributor: David Featonby , UK (da.featonby@gmail.com)

Tea Time

Black Tea Indicator

Science: Acids and bases

Age Range
Middle School/Secondary

Science Principle
Acidic, basic and neutral solutions and pH indicators

Equipment/material needed
- Black Tea
- Water
- Kettle
- Vinegar
- Lemon
- Glass cleaner

Description

1. Make some black tea.
2. Let it cool down.
3. Distribute the tea into three containers.
4. To the first add a few drops of an acid solution, such as vinegar or lemon juice.
5. To the second add a few drops of a glass cleaner.
6. One of the containers will serve as a control, to compare the colour.
7. Look at the colours of the three containers and draw your own conclusions.
8. You can enjoy and explore the pH of various foods you have in the kitchen.

Figure 1. Make some black tea.

Figure 2. Distribute the tea into three containers.

Conclusion/Result

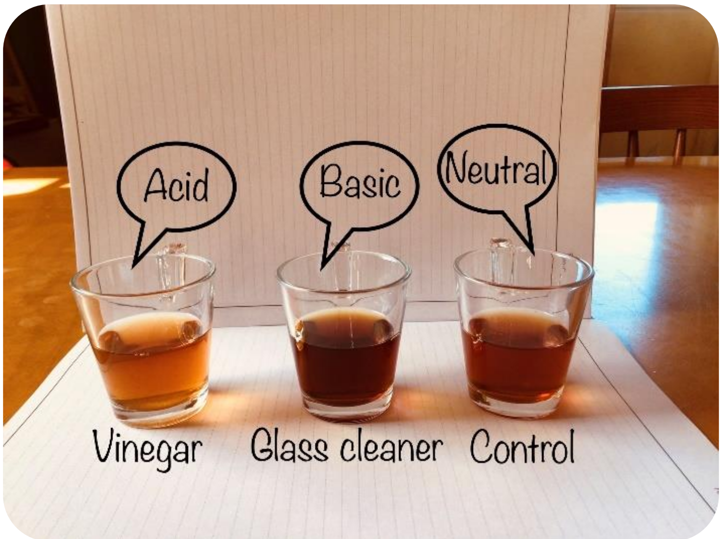


Figure 3. The result after adding acid and basic solutions.

Why does the tea lighten in an acidic medium and darken in a basic medium?

The leaves of black tea contain a large amount of thearubigins. Thearubigins are polymeric polyphenols, the pigment responsible for the drink's colour. This pigment acts as a pH indicator, causing the tea to lighten in an acidic medium. And when we add a basic solution like glass cleaner the tea darkens. Basic dissociated forms of these compounds have strong absorption of visible light this absorption decreases a lot in acidic environment.

A colorimetric pH indicator is a substance that distinguishes between acidic, basic and neutral solutions by changing their colour. In the laboratory we use indicators such as phenolphthalein, litmus blue or a universal indicator. But in our kitchen, we can use indicators within reach, such as the one found in black tea.

Next time observe this phenomenon when you put a piece of lemon into your black tea.

Top Tips:

Observe safety precautions when working with boiling water.

Adult supervision is required.

Contributor: Rute Oliveira, Portugal (rute.oliveira1975@gmail.com)

Floating Dough Balls in Water

Science: Average density and CO2 release

Age Range

Primary /Secondary

Science Principle

Release of CO_2: Heat is responsible for the decomposition of yeast and baking soda, releasing CO_2 which in turn reduces the density of the balls.

Equipment/material needed

- Dough balls recipe, flour, oil
- Additives for balls: yeast, baking powder
- Clock
- Beakers of warm water

Description

Dough balls are made with flour and oil. There are various combinations which include sugar, salt water and milk, all of which alter slightly the properties of the balls. Three different doughs are made with wheat flour, one contains extra additional baking powder and another additional yeast. When the ball with no additives is dropped into “warm” water it sinks. And the question that Lois asks is, what happens to the other balls…

Details of the experiment in Lilu's House can be found here in “Lilu’s House – Language Skills through Experiments”, chapter Kitchen, page 50

https://www.science-on-stage.eu/material/lilus-house

Doughballs with additives

1. Yeast
2. Baking powder
3. No additive

Figure 1: materials

Conclusion/Result

The key here is the release of carbon dioxide as bubbles within the dough, this reduces the density of the dough ball. The dough reacts with slightly warm water, so that with the baking powder the carbon dioxide was released fairly quickly and initially held within the dough, reducing its density so it floats immediately. Had we used very cold water in the dough it would have sunk and then risen within a minute or so. Within the 30-minute wait with our lump the carbon dioxide escapes and leaves a messy lump of dough resting on the bottom of the glass.

The yeast takes longer to release its carbon dioxide, so the dough takes a lot longer to rise.

Figure 2: Dough Balls in warm water, immediately after dropping in, and 30 minutes later

Top Tips: Clear up afterwards

Internet links:

Facebook Group "What Happens Next Experiments" DOUGH BALLS and DENSITY 5th and 6th September 2020

Details of the experiment in Lilu's House can be found here

https://www.science-on-stage.eu/material/lilus-house

Contributor: David Featonby , UK (da.featonby@gmail.com)

Photos from Lois Featonby

Redox reactions with Lollipops

Science: Use a lollipop to activate colour-changing redox reactions in this simple but eye-catching activity

Age Range

Primary /Secondary

Science Principle

This is a vivid colour-changing demonstration to illustrate a chain of re-dox reactions, whereby electrons are transferred between different com-pounds and ions.

Equipment/material needed

- Potassium permanganate ($KMnO_4$) crystals
- Spherical lollipop containing glucose (or other reducing sugar, e.g. fructose)
- 3-4 sodium hydroxide (NaOH) pellets (approximately 0.5 g)
- 200 mL distilled water
- 250 mL conical flask or beaker (glass or plastic)
- Spoon and spatula
- Miniature electric whisk, e.g. hand-held milk frother
- Adhesive tape

Description

A full discussion can be found in Science in School , March 2018

https://www.scienceinschool.org/article/2018/colourful-chemistry-redox-reactions-lollipops/

Figure 1 - Apparatus

Figure 2 - David with lollipop

Figure 3 - Close up of lolly taped to milk frother

The redox chemistry of manganese is a fascinating aspect of transition metal chemistry. This simple practical exercise helps students to familiarise themselves with the variable oxidation states of manganese and their respective colours. Observing the different colours will elicit discussion and will be a point of focus for understanding what is happening in the redox steps in the reaction.

In a series of redox reactions, electrons are donated continually from glucose to successive compounds of manganese. At each step in the chain, a colour change is visible. Manganese is ideal for this experiment, as it has more stable oxidation states than any other transition metal (from +2 to +7), each of which has a different colour.

In our experiment, glucose is added to a permanganate solution together with sodium hydroxide (NaOH), so electrons from glucose ($C_6H_{12}O_6$) are first donated to permanganate ions (MnO_4^-). The oxidation products of the reducing sugar are mainly glucuronic acid ($C_6H_{10}O_7$), plus some arabinonic acid ($C_5H_{10}O_6$) and formic acid (CH_2O_2). If the lollipop is made from fructose, which is an isomer of glucose, the main product is fructonic acid (also $C_6H_{10}O_7$).

By using a lollipop, the glucose is added gradually to the solution, which makes it easier to follow the colour changes. Using a miniature electric whisk means the lollipop is stirred faster than by hand.

The activity is suitable for a single lesson. The experiment takes only about 15 minutes and can be followed up by a set of discussion questions. The steps are as follows:

1. Fill the flask or beaker with 200 mL of distilled water.
2. Stir in the NaOH pellets with the spoon until they have dissolved completely.
3. Using the spatula, add a few potassium permanganate crystals (not too many, or the colour will be too dark to see the changes). When potassium permanganate ($KMnO_4$) is added to the alkaline NaOH solution, it dissolves into potassium (K^+) and permanganate (MnO_4^-) ions.
4. Attach the stick of the unwrapped lollipop to the mini electric whisk using adhesive tape (figure 3).
5. Insert the lollipop into the solution and switch on the whisk to start mixing.

As the lollipop dissolves into the solution, you will observe colour changes for each redox reaction. The first two changes happen very rapidly (3-5 seconds), while further changes take a little longer. Students can take photos (e.g. with the camera of a mobile phone) at various time points to better compare and follow the changes in colour. A video from the authors demonstrating the experiment is available in Spanish.

Conclusion/Result

As the lollipop dissolves in the solution containing manganese ions, at least five different colours can be distinguished (figures 4-8), which correspond to different oxidation states of manganese.

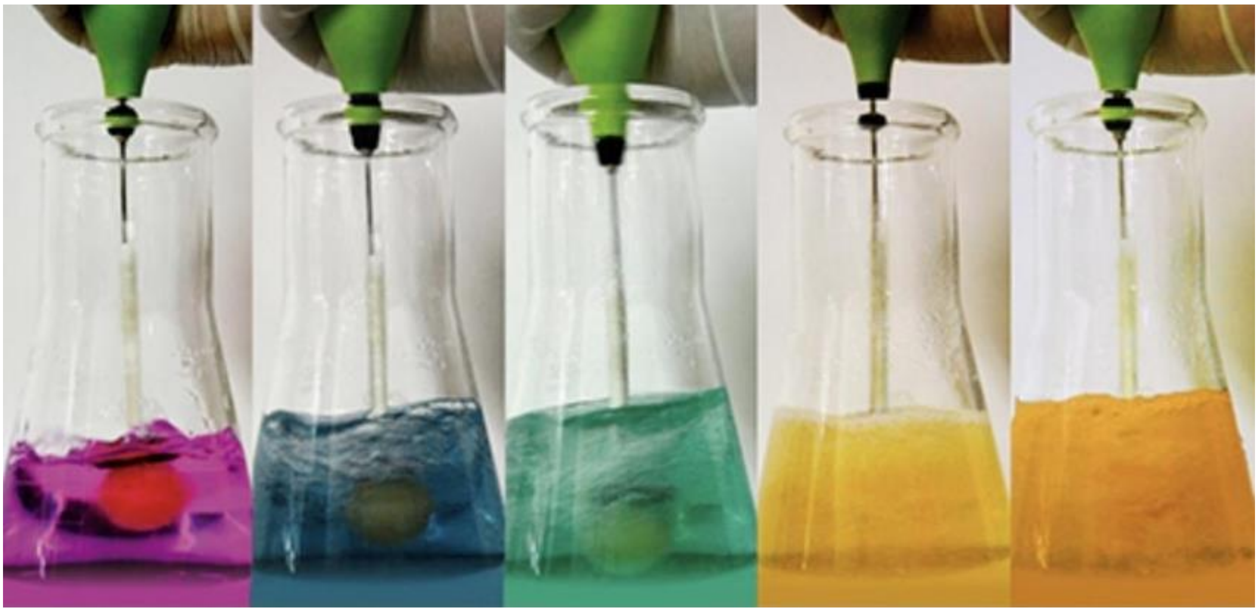


Figure 4: The first colour in the chain of redox reactions is purple, which corresponds to the permanganate ions.

Figure 5: Before the colour changes from purple to green, there is a blue intermediate stage.

Figure 6: Permanganate ions are reduced to manganate ions, resulting in a colour change to green.

Figure 7: Manganate ions are reduced to manganese dioxide, causing the colour to change from green to yellow-brown.

Figure 8: The final colour change is to orange, when manganese dioxide forms a colloidal suspension in the alkaline solution.

1. The first colour (purple) corresponds to permanganate ions (MnO_4^-). Manganese has the oxidation state +7 (figure 4).

2. The permanganate ions (MnO_4^-) are then reduced to manganate ions (MnO_4^{2-}). The oxidation state of manganese changes from +7 to +6, and the colour changes from purple to green (figure 6). MnO_4^- (aq) (purple) + e^- → MnO_4^{2-}(aq) (green) An intermediate blue stage occurs between steps 1 and 2 (figure 5). One explanation is that the mixture contains both the purple permanganate (MnO_4^-) and the green manganate ions (MnO_4^{2-}), which combine to produce a blue solution. Another explanation is that a part of permanganate is reduced to hypomanganate (MnO_4^{3-}), which has an oxidation state of +5 and a blue colour. MnO_4^- (aq) (purple) + $2e^-$ → MnO_4^{3-}(aq) (blue)

3. The manganate ions (MnO_4^{2-}), which have an oxidation state of +6, are further reduced to manganese dioxide (MnO_2), with an oxidation state of +4, causing a colour change from green to yellow-brown (figure 5). MnO_4^{2-}(aq) (green) + 2 H_2O(l) + $2e^-$ → MnO_2 (s) + $4OH^-$ (aq) (yellow-brown) 4. Finally, when even more glucose is incorporated into the solution, brown-black manganese dioxide (MnO_2) forms a colloidal suspension in alkaline solution, which (if fairly dilute) can appear orange (figure 8).

Background information: Electron configuration and transition metals

Electrons are arranged in energy levels called shells. Each shell is divided into subshells, which are made up of orbitals. Transition metals have one or more electrons in their outermost d-orbital. The difference in energy between individual d-orbital electrons is relatively small, so all transition metal cations have a variety of ways of forming chemical bonds involving different numbers of d-orbital electrons. This is why transition metals have several oxidation states. When electrons absorb certain frequencies of electromagnetic radiation, they jump to a higher energy level. In many transition metals, the difference in energy between d-orbitals corresponds to the energy of radiation of the visible light spectrum. For example, the d-orbital electrons of permanganate ions absorb electromagnetic radiation from the yellow part of the visible spectrum, but what we see as the colour of permanganate ions is the colour complementary to yellow – that is, purple. We see the colour of the remaining wavelengths that were not absorbed (figure 9).

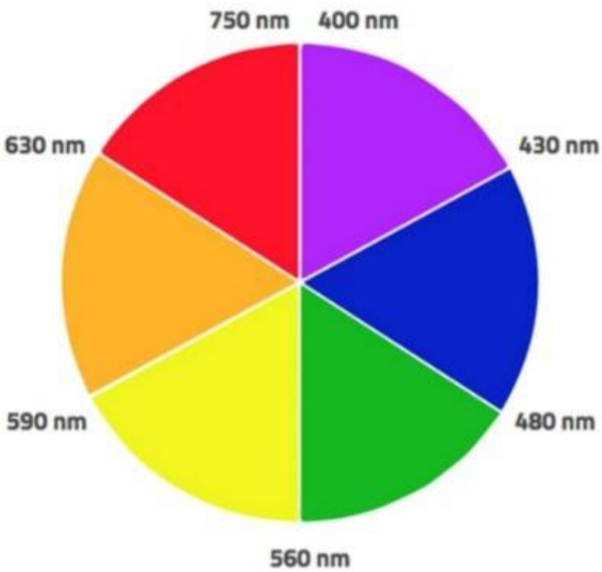


Figure 9 - The colour of the solution is the colour that is complementary (i.e. opposite on the colour wheel) to the wavelength of light absorbed by d-orbital electrons.

Internet links: See also https://edu.rsc.org/exhibition-chemistry/demonstrating-the-chameleon-redox-reaction-with-a-lollipop/4016633.article

Video of the experiment in Spanish: https://www.youtube.com/watch?v=1pE3U7UkIqc&ab_channel=IesManuelRomero

Further ideas: Variations of this experiment can be performed in a number of different ways. For example, rather than using a lollipop, you could use a chewing gum containing sugar as the reducing agent; or instead of adding the glucose to a flask, you could add it to a plastic bottle and shake it to observe the colour changes. Your students could use their creativity to think of alternative experiments.

Resources: For ideas on introducing redox reactions using everyday examples, see: Voak H (2016) Redox resources. Science in School 36. www.scienceinschool.org/ content/redox-resources

www.scienceinschool.org/content/artistic-introduction-anthocyanin-inks

Safety note. Teachers should follow their local health and safety rules, in particular concerning the use of potassium permanganate and the disposal of the resulting solution.

Contributors: Marisa Prolongo (Spain) Gabriel Pinto (Spain)

David Featonby (UK)

Sugar and Salt

Science: Different action of “salts” with water, molecular mixes

AGE RANGE

Primary /Secondary/specific age group

SCIENCE PRINCIPLE

Different ways in which things dissolve.

EQUIPMENT/MATERIAL NEEDED

- Salt
- Sugar
- Water
- 100 mL measuring cylinders

Description

Two measuring cylinders are filled to about 30 mL, one with salt and one with sugar (Figure 1).

Figure 1: Cylinders with salt and sugar

Figure 2 Cylinders filled with coloured water

Coloured water is then poured into the cylinders to a depth of 50 mL (Figure 2). The levels of the water are observed over time, (30 minutes suggested).

Conclusion/Result

The water in the sugar cylinder remains at the 50-mL mark, whereas the water level in the salt cylinder falls by a few mL. (Figure 3)

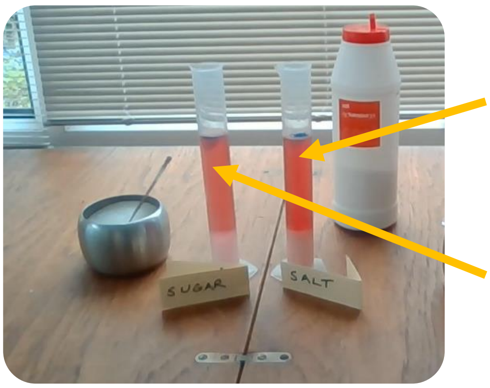


Figure 3

Water level above salt has fallen.

Water level above sugar remains the same.

Salt in water breaks down into positive and negative ions Na^+ and Cl^-. These ions are small enough to fit into the gaps within the water between molecules. The larger sugar molecules are too large to fit into the gaps.

Top Tips: Coloured water helps us see.

Contributor: David Featonby, UK (da.featonby@gmail.com)

The Colour of Salts in a Flame

Science: The colour of the salt

Age Range
Primary /Secondary

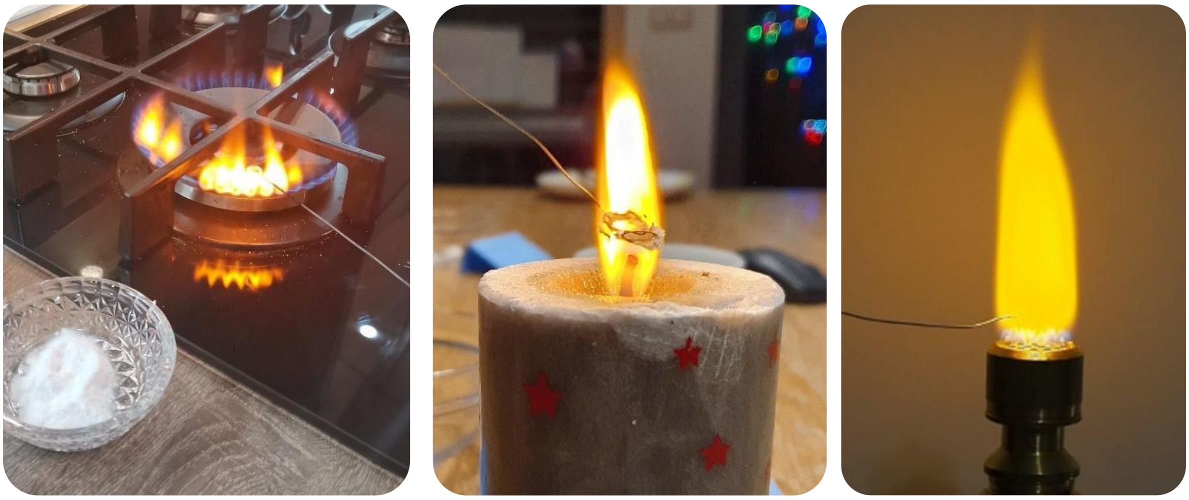
Science Principle
Chemists use the flame test to determine which metals are present in a sample, because different metals tint the flame different colours.

Equipment/material needed

- table salt
- vinegar
- candle or burner
- platinum wire
- glass cup

Description

1. At the end of the wire make a small eye.
2. Lower the eye of wire into the vinegar that is in the cup and hold it in the flame of the candle/burner to cleanse and burn impurities.
3. Lower the eye of wire again into the vinegar and then into the table salt.
4. Hold the wire with salt in the flame of the candle/burner and observe the coloration or changes of flames coloration.



Figures 1-3: The yellow flame of the natrium from the table salt.

Conclusion/Result

The chemical formula of table salt is NaCl. Table salt contains metal, natrium in the form of ion Na^+. When things burn, and metals are no exception, ions and atoms leave the burning material for the air. When they first appear, they are in a so-called "excited state", meaning that some of their electrons are not occupying the most "comfortable" positions. These electrons are quick to settle more "conveniently" though, and as they do so, they emit some light.

One interesting thing about this light is that its colour is very specific to the kind of atom or ion that emitted it. That is why different metals tint the flame in different colours. Chemists use this effect to determine which metals are present in a sample.

The yellow flame you see while burning table salt is due to the natrium's emission spectrum.
And that is the reason why the flame on your stove suddenly turns yellow when salting a soup and some grains of salt fall out of the pot.
Other salts can be tested, for example pink salt or Himalayan black salt, to investigate whether the flame will have other colours.

Top Tips:

- Natrium is an element that is normally found in many different agents and substances used in households. So that is why you can carry out the flame test not just with table salt.
- If you don't have a platinum wire, you can use some copper wire (The green flame you see while holding the wire in the flame is caused by the copper. If you put table salt on it, the colour of the flame will change).

Internet links: https://youtu.be/UoWXl5l-ZRw, https://youtu.be/oPTiNj_tQb4

Contributor: Lucia Dovalová, Slovakia (dovalova.lucka@gmail.com)

Blue Tea as an Acid-Base Indicator

Science: Acids and bases

FOOD, COOKING AND STEM

Age Range

Students aged 14–19; also suitable for ages 11–14 if there is less emphasis on the theory behind the chemical reactions.

Science Principle

In this activity, we explore the colour changes that occur when an acid and a base are added to a striking blue-coloured infusion of butterfly pea flower tea. Blue tea as an acid–base indicator.

Equipment/material needed

- Butterfly pea flower tea (also called blue tea)
- Half a lemon
- Household ammonia (ammonium hydroxide, NH_4OH, as 5% to 10% solution in water). Alternative: Baking soda (sodium hydrogencarbonate, $NaHCO_3$)
- Water
- Stirring rod
- 3 test tubes
- 3 small containers (e.g. plastic cups)
- water boiler
- Dropper
- Teaspoon (if sodium hydrogencarbonate is used)

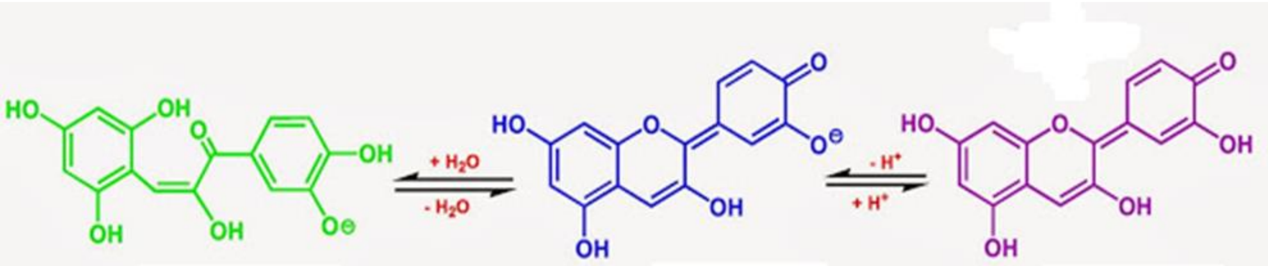
Description

1. Prepare an infusion of butterfly pea flower tea and allow to cool to room temperature. This should be done at the start of the lesson.
2. Squeeze half a lemon and collect the juice in a cup.
3. Pour a small amount (2-3 mL) of household ammonia (if used) into a cup.
4. Place approximately 20 mL of the infusion at room temperature into each of the three test tubes.
5. Using the dropper, add three to four drops of lemon juice to one of the test tubes, and three to four drops of ammonia to the other. Alternatively, instead of the ammonia, add a teaspoon of sodium hydrogencarbonate to the second test tube. Leave the third test tube as a control.
6. Shake the first and second test tubes gently to homogenize the mixtures.
7. Observe and record the changes that occur in the colours of the liquids contained in the three test tubes, if any.

Figure1: Infusion of butterfly pea flower tea (left); after adding lemon juice (centre); and after adding ammonia (right).

Conclusion/Result

In the activity, students should see the following colour changes (see figure 2): These colour changes occur because butterfly pea flower tea contains molecules called anthocyanins. These molecules alter the wavelength of light they absorb, and therefore their colour, depending on the pH of the solution they are in. Lemon juice contains citric and other acids, so adding this to the tea produces a more acidic (lower pH) solution and a visible colour change. Adding a weak base such as ammonium hydroxide or sodium hydrogencarbonate decreases the number of hydrogen ions, leading to a lower acidity (higher pH value) and another colour change.



pH > 9 **pH 6-9** **pH < 6**

Figure 2: Different forms of an example of anthocyanin, in solution of varying pH. The colour of the molecule represents that of its aqueous solutions.

Anthocyanins are a group of water-soluble pigments responsible for the red, blue, or purple colouration of many flowers, fruits (including blueberries and raspberries), and vegetables (such as red cabbage). These pigments are also partly responsible for autumn leaf colours.

The region of these pigment molecules that produces the colour is called the chromophore. In the chromophore region, the energy difference between two molecular orbitals falls in the range of the visible-light spectrum. Adding a hydrogen ion to a chromophore can change its wavelength of absorbance, and thus its colour. Because the acidity of a solution (or pH value) depends on the concentration of hydrogen ions, chromophores – and the plant material containing them – potentially act as natural acid-base indicators. There are many examples of colour changes involving pH-sensitive anthocyanins and other vegetable dyes.

Top Tips: The activities can be completed in one lesson (approximately 60 minutes), and we recommend that students work in groups of 3–4. Optionally, students can use the video feature on their cell phones to record and review the changes they see.

Internet links: https://www.scienceinschool.org/article/2021/tea-time-chemistry/

Rusishvili M et al. (2019) Unraveling the molecular mechanisms of color expression in anthocyanins, Physical Chemistry Chemical Physics 21: 8757-8766. doi: 10.1039/C9CP00747D

Contributor(s): Marisa Prolongo, Spain (marisaprolongo@hotmail.com) and Gabriel Pinto, Spain (gabriel.pinto@upm.es)

Coke & Casein

Science: Precipitation of casein by decreasing the pH

Age Range

14 – 17 years

Science Principle

Precipitation of casein by decreasing the pH.

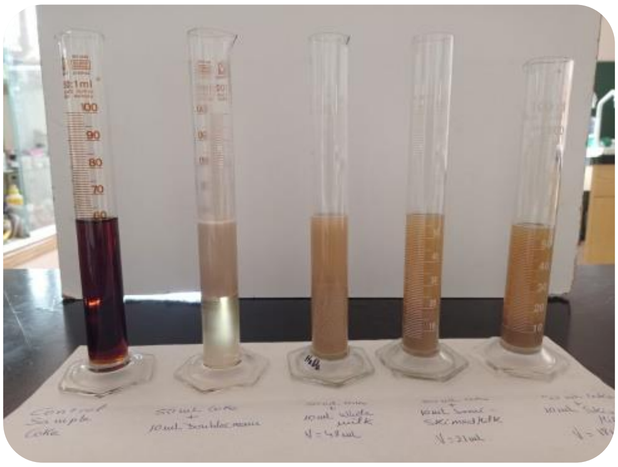
Equipment/material needed

- Different types of milk: skimmed milk, semi-skimmed milk, whole milk, double cream
- Bottle of cola 1 L
- Four transparent glasses

Description

1. Open the bottle of Coke and pour approximately 50 mL in every glass.
2. Then add 10 mL of milk, each kind of milk in a different glass.
3. Pay attention to what happens next: changes occur slowly but are easily seen.

Figure 1: 50 mL of Coke + 10 mL of milk in each graduated cylinder



Picture 2: Precipitation of casein

Conclusion/Result

The most important proteins in milk are the caseins, which form a colloidal dispersion. This is because, with the pH of milk (around 6.6), the electrical charges that predominate in these molecules are negative, so that the net charge is negative. This causes a repulsion between the proteins and thus they remain in balance.

Science: Precipitation of casein by decreasing the pH

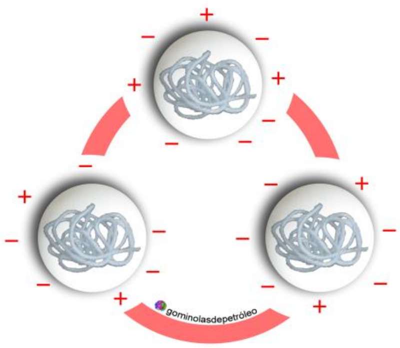


Figure 3: Caseins are the most important proteins in milk, in which at normal pH (6.6) they have a net negative charge. https://gominolasdepetroleo.com

Cola contains different acids (mainly carbonic acid and, above all, phosphoric acid), so its pH is quite low (around 4). When we add milk to soft drinks, the charge on the proteins changes, so that as the pH decreases, the number of positive charges increases. When the pH is 4.7, the net charge is null, so, the negative and positive charges are equal (this is called the isoelectric point), so that the proteins bind to each other and the balance that existed until now is broken. Throughout these unions, large and heavy aggregates are formed that cannot be kept in suspension, so they precipitate, dragging other substances along with them, such as those that provide colour to the cola.

When we add double cream to a soft drink the same phenomenon occurs but with a clear difference, the casein aggregate floats in the whey as it is surrounded by excess fat molecules that are less dense than water.

Top Tips: An easy activity that the student can carry out on their own. Meanwhile they are learning about proteins and the effect of the pH in its precipitation.

Internet links: https://youtu.be/Vos2YFgubYA

Contributor: Nuria Muñoz, Spain (algenuria@gmail.com).

Identifying Tannins in Black Tea

Science: Polyphenols in tea

Age Range

Students aged 14-19; also suitable for ages 11-14 if there is less emphasis on the theory behind the chemical reactions

Science Principle

This experiment uses a solution containing iron(III) ions to produce a colour change indicating the presence of polyphenols such as tannins in tea.

Equipment/Material Needed

- Black tea leaves or tea bag
- Water at room temperature
- Stirring rod
- Two test tubes
- Aqueous iron(III) solution
- Small container (e.g. plastic cup)
- Dropper

Description

This experiment uses a solution containing iron(III) ions to produce a colour change indicating the presence of polyphenols such as tannins in tea. The solution should be prepared by the teacher before the class by dissolving a teaspoon of iron(III) chloride hexahydrate in 50 mL of water. Alternatively, a steel pan scourer or steel wool can be used, although in these cases the colour change will be slower. When using the iron(III) solution, it is instantaneous.

Students should work through the following steps:

1. Prepare a weak infusion of black tea using hot or room-temperature water. Allow to cool if hot water is used. This should be done at the start of the lesson.
2. If necessary, dilute the prepared infusion with water until it is a pale brown-yellow colour.
3. Pour approximately 20 mL of the infusion into each of the two test tubes.
4. Add 3–4 drops of diluted iron(III) chloride to one of the test tubes.
5. Alternatively, pour about 50 mL of infusion into a beaker, then add steel wool and heat to boiling, shaking gently to homogenize the mixture.
6. Leave the second test tube as a control.
7. Observe and record the changes that occur in the first test tube. An example can be seen in Fig.1.

Figure 1: An infusion of black tea (left), and after adding an aqueous solution of iron(III) chloride (right)

Conclusion/Result

In the activity, the tea darkens when iron(III) ions are present, changing from pale brown to black, with the appearance of ink (see Fig. 1). The compounds responsible for this change are polyphenols, which react with the iron ions. Tea contains a number of polyphenols, including tannins that give it bitterness and astringency, and an example of these polyphenols is gallic acid and its derivatives, which are part of the structure of several tannins. The chemistry involved is rather complex, but in short, the gallic acid reacts with iron(III) ions to form ferric pyrogallate, a black insoluble complex ion.

Figure 2 shows an example of a complex of gallic acid and iron(III), with two molecules of water acting as co-ligands to complete the octahedral coordination sphere.

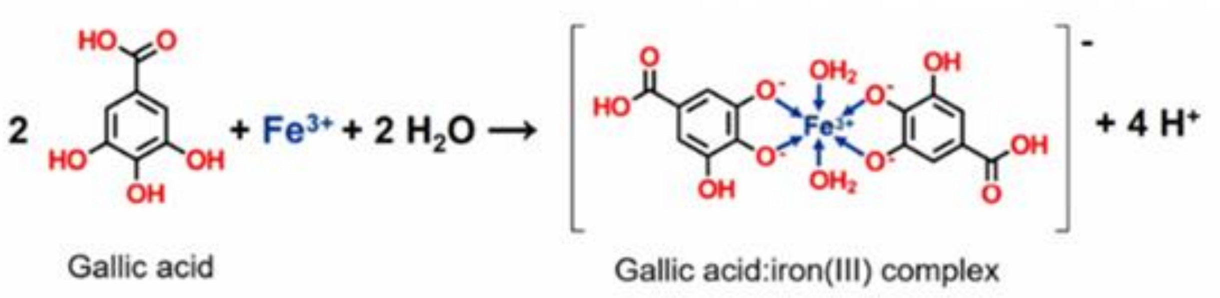


Figure 2: Formation of a gallic acid and iron(III) complex.

Top Tips: This activity can be used as a starting point to discuss how transition metal complexes are formed (the type of bonding involved, what ligands are, and how pH changes affect formation).

A lab coat, gloves, and safety glasses should be worn by all students to avoid contact of the chemicals with skin and eyes. Particular care should be taken with the iron(III) chloride.

Internet links: https://www.scienceinschool.org/article/2021/tea-time-chemistry/

Rattanakit P, Maungchang R (2019) Determining Iron(III) Concentration in a Green Chemistry Experiment Using Phyllanthus emblica (Indian Gooseberry) Extract and Spectrophotometry, Journal of Chemical Education 96:756-760. doi: 10.1021/acs.jchemed.8b00817

Contributor(s): Marisa Prolongo, Spain (marisaprolongo@hotmail.com) and Gabriel Pinto, Spain (gabriel.pinto@upm.es)

Redox Reactions with Hibiscus Tea

Science: Colour changes due to the action of oxidizing and reducing agents on hibiscus

FOOD, COOKING AND STEM

Age Range

Students aged 14-19; also suitable for ages 11-14 if there is less emphasis on the theory behind the chemical reactions

Science Principle

In this activity, we look at colour changes due to the action of oxidizing and reducing agents on hibiscus tea. Here, sodium percarbonate acts as the oxidizing agent and sodium dithionite as the reducing agent.

Equipment/material needed

- Infusion of hibiscus tea
- Sodium percarbonate (also known as sodium peroxycarbonate), $2Na_2CO_3 \cdot 3H_2O_2$
- Sodium dithionite (also known as sodium hydrosulfite), $Na_2S_2O_4$
- Water, water boiler
- Stirring rod
- 3 test tubes
- 3 small containers (e.g. plastic cups)
- Dropper
- Tablespoon

Description

1. Prepare a hibiscus infusion and let it cool down to room temperature. This should be done at the start of the lesson.
2. Dilute the prepared infusion with water until pale in colour (to better appreciate the colour change) and introduce approximately 20 mL of this liquid into three test tubes.
3. Add a quarter teaspoon of sodium percarbonate to one of the test tubes and shake it gently to homogenize the mixture.
4. Repeat with a quarter teaspoon of sodium dithionite, adding this to the second test tube and shaking it gently to homogenize the mixtures.
5. Leave the third test tube as a control.
6. Observe and compare the final colours of the liquids in the three test tubes.

Figure1: Tube 1: hibiscus tea; Tube 2: hibiscus tea with sodium percarbonate; Tube 3: hibis-cus tea with sodium dithionite

Conclusion/Result

The hibiscus tea discolours (bleaches) almost completely with sodium dithionite, but not with sodium percarbonate (figure 1).

Chemical bleaches are products used to remove colour from fabric and to clean stains. They react with many coloured organic compounds, including natural pigments. Oxidizing agents are most commonly used, but some reducing agents are also used.

Sodium percarbonate is a typical peroxide-based oxidizing bleach. The peroxide group gives rise to very reactive oxygen species, and these are the active bleaching (and oxidizing) agents. They break apart chemical bonds in the chromophore region of the pigment molecules, changing their colour.

A reducing bleach, such as sodium dithionite, works by converting the carbon–carbon double bonds in the chromophore to single bonds, thereby decreasing the oxidation state of the carbon.

Top Tips

Although most of the reagents are common household chemicals, some, such as ammonium hydroxide solution, sodium percarbonate, and sodium dithionite, can be irritants or corrosive.

Search for information about bleaches and fabric whiteners on the internet. What chemical substances are typically used in these products?

Look for information about the presence of dithionite and percarbonate salts on the labels of laundry products sold in supermarkets. What do you find?

Internet links

https://www.scienceinschool.org/article/2021/tea-time-chemistry/

Investigate antioxidants in food and drinks: Farusi G (2009) Looking for antioxidant food. *Science in School* **13**: 39-43.

Contributor(s): Gabriel Pinto, Spain (gabriel.pinto@upm.es) and Marisa Prolongo, Spain (marisaprolongo@hotmail.com)

FOOD, COOKING AND STEM

Spherification

How to transform liquid into semi-solid balls

Science: Molecular gastronomy

Age Range

Secondary

Science Principle

chemical reaction, solution, pH

Equipment/material needed

- Measuring cup
- measuring spoons (1 teaspoon, 1 tablespoon)
- electric blender
- spoons (for stirring etc.)
- 4 medium sized bowls
- container with lid
- pipette or syringe
- mesh strainer
- 300 mL tasty liquid such as cola, fruit juice, tea (liquid that is not too acidic and doesn't have too much calcium)
- 0.5 teaspoon sodium alginate
- 1 teaspoon calcium chloride
- 300 mL water.

Description

1. First, we prepare the alginate-grape juice solution, following these steps:

   1.1. Put 300 mL grape juice in a medium bowl.
   1.2. Sprinkle the alginate over the grape juice.
   1.3. Use your electric blender to blend the mixture for approximately 2 minutes(you may have more or less foam, depending on the liquid you are using).

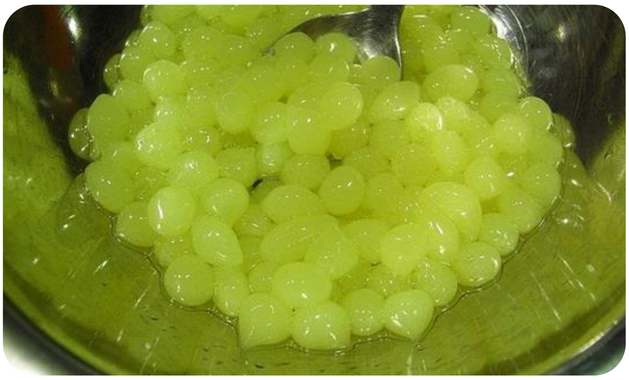
   1.4. Store the mixture in the fridge for at least 1 h or overnight to get rid of the foam. Too many bubbles in the solution can make it more difficult to form the balls in the next steps.

2. After that we prepare the calcium chloride solution:

   2.1. Measure 300 mL water into a medium bowl.
   2.2. Add 1 teaspoon of calcium chloride.
   2.3. Stir the solution until the calcium chloride is dissolved.

3. Now we are ready to create the spheres:
    3.1. Using a syringe or pipette, add the alginate-grape juice solution to the calcium solution one drop at a time, holding the syringe or pipette approximately 5 cm above the surface of the calcium lactate solution.
    3.2. Allow the spheres to solidify for a couple of minutes.

4. The last step is washing the spheres:
    4.1. Pour the calcium chloride solution and all the formed spheres through a mesh strainer (placed another container under the strainer to collect the calcium lactate solution).
    4.2. Rinse the spheres by swishing them in a bowl of fresh water.
    4.3. Serve the spheres and eat them. Enjoy!



Conclusion/Result

Spherification is based on a specific chemical reaction. This reaction takes place between sodium alginate and calcium chloride. Sodium alginate is made from seaweed and consist of alginate, a negatively charged molecule called a polysaccharide, and positively charged sodium ions that bind to the alginate molecules. When dissolved, the sodium alginate creates a liquid solution as the sodium ions dissociate from the alginate molecules. When sodium alginate is dropped into a calcium chloride solution, the alginate molecules bind to the calcium ions, forming calcium alginate. As the doubly charged calcium ions can bind two different alginate molecules simultaneously, the solution thickens and becomes a gelatinous substance (Figure 1)

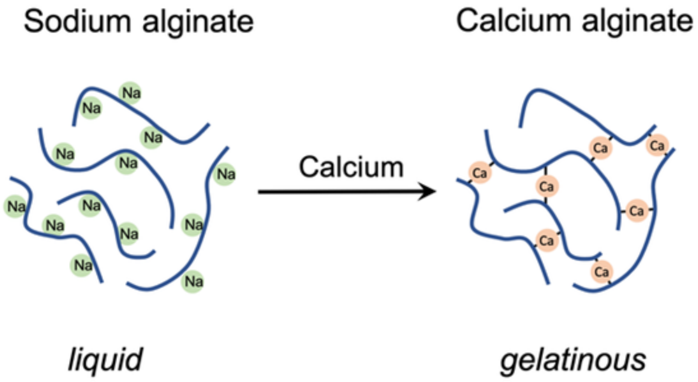


Figure 1: Schematic drawing of the chemical reaction between sodium alginate and calcium chloride.

Sodium alginate ($NaC_6H_7O_6$) can react with calcium chloride ($CaCl_2$) to make calcium alginate ($C_{12}H_{14}CaO_{12}$), which is a gelatinous substance (Equation 1).

$$2\ NaC_6H_7O_6 + CaCl_2 \rightarrow 2\ NaCl + C_{12}H_{14}CaO_{12}$$

Top Tips: One factor that affect the process of spherification is the pH of the liquid you use, if it is too acidic, spherification will not work well. To solve this problem, sodium citrate can be added to the food. Sodium citrate and water make a basic solution, so when it is added it makes the food less acidic. However, if too much sodium citrate is added, spheres don’t form; just the right amount of sodium citrate needs to be added. (This is because sodium citrate can bind to calcium and prevent the calcium from participating in the spherification reaction, shown in Equation 1).

Internet links: https://isbscience.org/ https://youtu.be/74RnO_wHX7k

Contributor: Nuria Muñoz, Spain (algenuria@gmail.com).

Chicken Liver

Science: Blood as a catalyst

AGE RANGE

Primary /Secondary

SCIENCE PRINCIPLE

The catalytic decomposition of hydrogen peroxide

EQUIPMENT/MATERIAL NEEDED

- Chicken liver
- Hydrogen peroxide
- Wooden splint
- Burner/candle
- Glass bowl
- Small cup
- Pipette/straw/syringe

Description

1. Put a piece of chicken liver into the glass bowl.
2. Drop a few drops of hydrogen peroxide on a prepared sample.
3. Make a splint smolder and see what happens when a smoldering splint touches the bubbles.

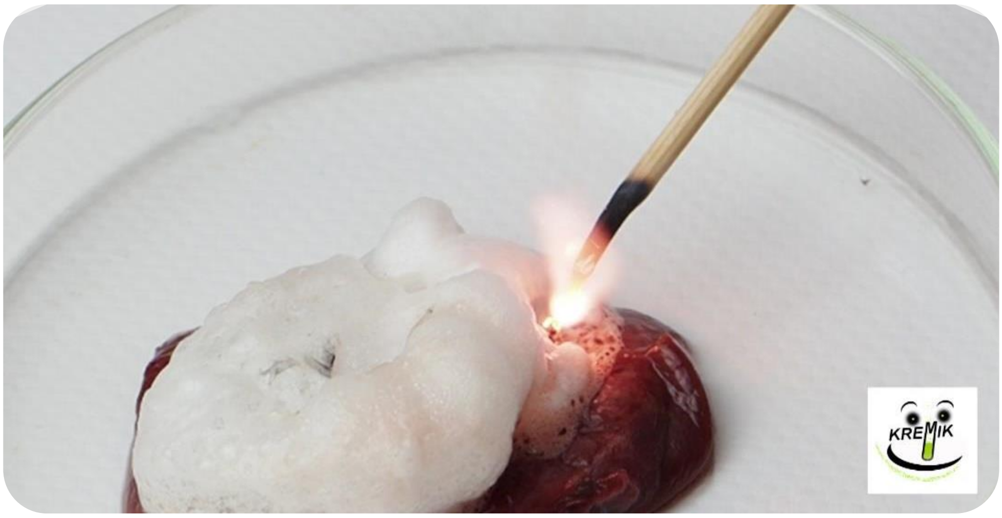


Figure 1. When a smoldering splint meets pure oxygen, it lights up.

Conclusion/Result

When the glowing splint is held near the bubbling hydrogen peroxide on the chicken liver it bursts into flame, showing the presence of pure oxygen.

Hydrogen peroxide decomposes even under normal conditions, but very slowly. If we want to increase the rate of decomposition/speed up reaction rates, we use a catalyst.

The catalytic decomposition of hydrogen peroxide is shown in the following chemical reaction:

$$2\ H_2O_2 \xrightarrow{\text{catalyst}} 2\ H_2O + O_2$$

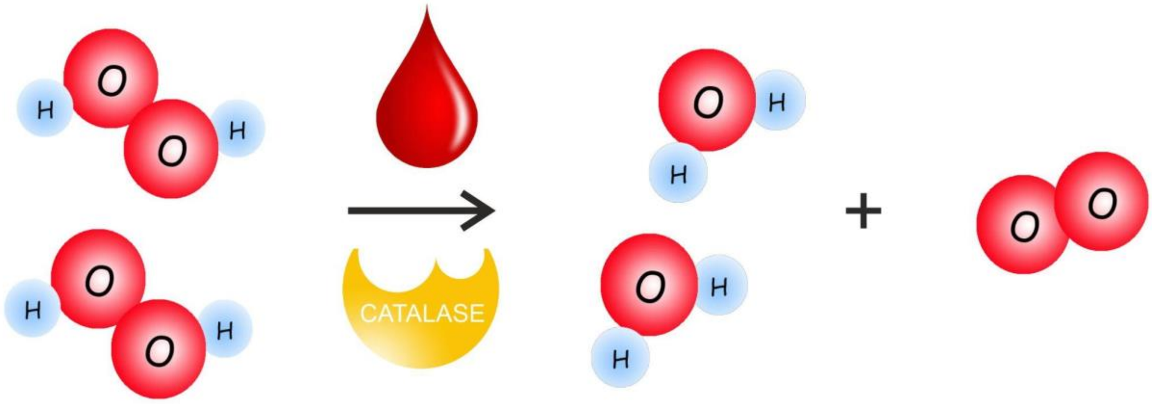
Chicken Liver

Science: Blood as a catalyst

The decomposition of H_2O_2 can be catalysed by platinum, manganese dioxide, silver, potassium iodide or blood.

In blood there is a catalase – enzyme (catalyst), that is important in protecting the cell from oxidative damage by reactive oxygen species from hydrogen peroxide. Hydrogen peroxide is formed in humans and other animals as a short-lived product in biochemical processes and it is toxic to cells. That's why it needs to be removed.

Among other things hydrogen peroxide is also used for the disinfection of wounds, because it destroys bacteria, viruses and microorganisms. When hydrogen peroxide interacts with blood from a wound, bubbling can be seen. This reaction is caused by the enzyme catalase, which decomposes hydrogen peroxide applied on a bleeding wound.



Bubbles are filled with gas - oxygen O_2. Oxygen is one of the conditions of combustion (burning), therefore we can prove its presence in bubbles by igniting a smoldering splint while it is in direct contact with oxygen in bubbles.

In kitchen conditions you can do the experiment with the chicken liver because it is full of blood and catalase in it.

Top Tips:

- Hydrogen peroxide is used for hair lightening and as a disinfectant - you can find the solution in drug stores/pharmacies.
- Put on protective gloves when handling hydrogen peroxide.

Internet links: https://youtu.be/taPJBgOBotM

Contributor(s): Lucia Dovalová, Slovakia (dovalova.lucka@gmail.com)

Snowstorm

Science: Sublimation and deposition of the benzoic acid

Age Range
Primary /Secondary

Science Principle
The transition directly from a solid to a gaseous state is called sublimation. The reverse transition, from a gaseous to a solid state, is called deposition.

Benzoic acid is a substance that can both sublimate and deposit.

Equipment/Material needed

- Candle or burner
- Glass mug (jam jar)
- Food pickling agent with benzoic acid
- Ice cubes
- Spoon
- Glass cup or bowl

Description

1. Add 1 spoon of food pickling agent containing benzoic acid to the glass mug.
2. Cover the mug with the glass cup with some ice cubes.
3. Start heating the mug carefully.
4. Heat for max. 2 minutes and observe the result.

Figure 1: The gaseous state

Figure 2: The storm in the glass

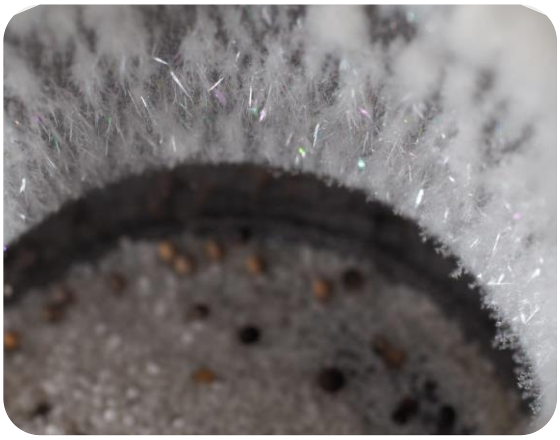


Figure 3: Crystals of the benzoic acid

Conclusion/Result

There are many chemicals that can sublimate. It means to change phase/state directly from a solid to a gas. To this group of chemicals also belongs benzoic acid which is used as a preservative for the conservation of food. Under normal conditions it forms odourless and colourless or white crystals. By heating above 100 °C benzoic acid sublimates. We can observe the creation of vapour. Gaseous particles of benzoic acid extend and when they are in contact with the ice cubes they cool down and deposit - a gas changes phase directly to a solid. We observe this phenomenon as the formation of small white crystals, which resembles a snowstorm.

The white vapour and shiny crystals are two states of one substance —benzoic acid. The transition directly from a solid to a gas state, by passing the liquid state, is called sublimation. The reverse transition, from a gaseous to a solid state, is called deposition. In the gaseous state, molecules of benzoic acid move quickly and freely, but as soon as they bump into a cold surface, they lose energy, instantly slowing down and getting closely together to form a solid. This resembles the process by which snowflakes or frost patterns form from water vapour in the air.

Top Tips and Safety Advice:

- Put on protective gloves, eyewear, and a mask.
- Keep flammable materials and hair away from flame.
- Heat only on a moderate flame - max 2 minutes
- Do not take the cover away from it during the process of heating where sublimation or deposition takes place, because its fumes are irritating and smelly.
- Wait another minute after heating is finished and only then uncover the jar/the mug.
- You can try to use other tools for this experiment (sublimation of benzoic acid). Use an aroma lamp with a candle. Instead of an evaporating dish of the aroma lamp, use a jam jar (glass one) to which you put benzoic acid and cover it with a bowl with ice. “Snowstorm” can be nicely seen through wall of glassed jar.
- Try putting for instance dead wood (dry branch), pinecone or a dry flower inside the glass where benzoic acid will sublimate.

Internet links: https://youtu.be/eeP9CUHcjr8, https://youtu.be/cR8m8mh44Mg

Contributor: Lucia Dovalová, Slovakia (dovalova.lucka@gmail.com)

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