CHEMICAL DEMONSTRATIONS BOOKLET

'exciting students about chemistry and helping them to understand chemical concepts'

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2021

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Chemistry is a visual subject and there are many abstract concepts which students find difficult to grasp. Chemical demonstrations can be a valuable tool for teachers to help students to understand difficult concepts and at the same time excite students about chemistry. Bassam Z. Shakhashiri in the book ‘Chemical Demonstrations: A Handbook for Teachers of Chemistry’ (Published by Univ of Wisconsin Press, 1989) states that ‘demonstrations capture interest, teach, inform, fascinate, amaze, and perhaps, most importantly, involve students in chemistry.’

For a number of years now I have been teaching first year foundations of chemistry unit to students who have no or very limited chemistry background. I observed that the students struggled with many chemical concepts and also were not as excited or interested in chemistry as I was, keeping their attention in a 2hr lecture was a challenge. I realised that I needed to do something to capture students’ attention and interest during the lecture. So I decided to bring ‘chemistry’ into the lecture theatre and perform chemical demonstrations during each lecture which were relevant to the topic being introduced and which helped students to grasp chemical concepts. However, finding chemical demonstrations which were safe enough to perform outside of the lab, didn’t take up too much time, were easy to implement and used relatively cheap chemicals was rather difficult.

I began to search for suitable demonstrations by talking to other chemistry lecturers, for example in 2005 I organised a workshop on the value of chemical demonstrations during the Royal Australian Chemical Institute National Convention Conference, examined literature and prepared my own demonstrations suitable for my foundation of chemistry unit.

Students were asked to comment on the use of these demostrations during my lectures and below are some of their responses:

Dr Wajrak demonstrating decomposition of H_2O_2 using a catalyst.

“The demonstrations are a great way to hold our attention and keep us interested while increasing our ability to remember the lecture content”

“The demo’s are great! They helped me so much and inspired me to investigate chemistry further”

“I think they are helpful because you remember the demos and therefore the reaction -> equations, it is easier to understand what is meant by the equations and I am more interested in chemistry because of them.”

“I would prefer more demonstrations. The demonstrations are great they DO help me understand. I am a visual person, when it comes to exams I remember the demos.’

“I believe the demonstrations used in our lectures were extremely useful learning tool. It helped me remember kinds of chemical reactions, colours and products of reactions.”

Encouraged by these comments I continue to perform chemical demonstrations in all my lectures. I have also, on many occasions, been invited to Secondary and Primary schools to perform these demonstrations and at various other outreach activities, such as the LabRats, Siemens Science Experience and National Science Week.

Many teachers have expressed interest in these demonstrations and therefore I decided to put together a booklet with detailed information about each demonstration. The original booklet was created in 2008. In 2010 I teamed up with Mr Tim Harrison, Teaching Scholar from the University of Bristol, UK, and we decided to collaborate on a new version of the booklet. Tim has contributed 15 of the chemical demonstrations in this booklet and performed these demonstrations to allow me to photograph them.

The demonstrations featured in this booklet are appropriate for a range of levels from year 7 up to year 12 and including foundation of chemistry units at University. Each demonstration has been thoroughly tested. For each demonstration, there is a list of equipment needed, preparation instructions, demonstration procedure and safety information (IMPORTANT: Please note that I have only provided basic safety information, you should consult relevent Materials Safety Data Sheets (MSDS) and your School's chemical disposal policy for more safety details with regard to the chemicals being used and their disposal. Also for all demonstrations it is expected that the demonstrator wears a laboratory coat, safety glasses, has enclosed shoes and long hair is tied back when performing these demonstrations) as well as educational outcomes and concepts covered. I have also provided photos of the equipment and how the demonstration looks like when it is performed.

I would like to say big thank you to Tim Harrison for his encouragement and contribution to this booklet, to Nardia Bordas, laboratory technician in the School of Science, ECU, for helping me to set-up and test these demonstrations and Ms Kerry Beake for the graphic design of the booklet.

I welcome any further comments/suggestions/criticisms about this booklet. Please contact me on:

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Dry ice in water

DEMONSTRATION 1: Distinguishing between chemical and physical change

Concepts:

- A physical change does not involve any permanent bond breaking/making and no new chemical is formed, only the state of the chemical is changed; eg. from solid to liquid
- A chemical change involves the breaking/making of permanent bonds and the formation of a new substance, identified by, for example, a change in colour or formation of a gas

Safety:

- Safety glasses MUST be worn at all times
- Do not touch dry ice (solid carbon dioxide) using bare hands – use tongs or insulated gloves
- Handle lead nitrate and potassium iodide with care – minimise contact with skin by wearing gloves if possible when handling these chemicals

Equipment:

Chemical Change

- 2 x large test tubes
- rubber stopper to fit test tube
- 15 g lead nitrate ($Pb(NO_3)_2$)
- 15 g potassium iodide (KI)
- black background

Physical Change

- dry ice in an esky
- tongs
- 250 mL conical flask or beaker
- black background

Figure 1. Equipment needed for chemical change demonstration.

Preparation:

Ensure that both $Pb(NO_3)_2$ and KI are in fine powder form, if not, grind-up separately each solid using a clean, dry mortar and pestle, prior to the demonstration.

Demonstration Instructions:

Physical Change

1. Using tongs, transfer some of the dry ice into a conical flask. Shake the flask to increase the rate of change from solid to gas.
2. Alternatively, using tongs, transfer some dry ice directly onto a black background and gently blow across the dry ice.

Chemical Change

1. Place about 15 g of lead nitrate into one test tube and about 15 g of potassium iodide into another test tube then transfer one solid into another.
2. Stopper the test tube and shake vigorously until there is a colour change. Wear gloves.

Figure 2. Left – transfer one solid from one test tube into another, middle – stopped the test tube and shake vigorously until there is a colour change, right – show students the result of this reaction.

Observations:

Chemical Change

Both lead nitrate and potassium iodide are white solids. Upon mixing, a yellow solid (lead iodide) is produced. A change in colour indicates chemical change rather than physical change.

Figure 3. Solid lead iodide.

Physical Change

A white vapour/cloud can be readily seen arising from the solid dry ice. This is condensed water formed as solid carbon dioxide converts to cold gaseous carbon dioxide. Inform students that at atmospheric pressure it is not possible to observe liquid phase (or state) of carbon dioxide.

Figure 4. Left – place dry ice on a black mat and blow over it, right – place dry ice into conical flask and shake the flask or add a few drops of water.

Chemical Equations:

Physical Change

$$CO_{2(s)} \rightarrow CO_{2(g)}$$

(white translucent solid) → (colourless gas)

Chemical Change

$$Pb(NO_3)_{2(s)} + 2KI_{(s)} \rightarrow PbI_{2(s)} + 2KNO_{3(s)}$$

(white) + (white) → (yellow) + (white)

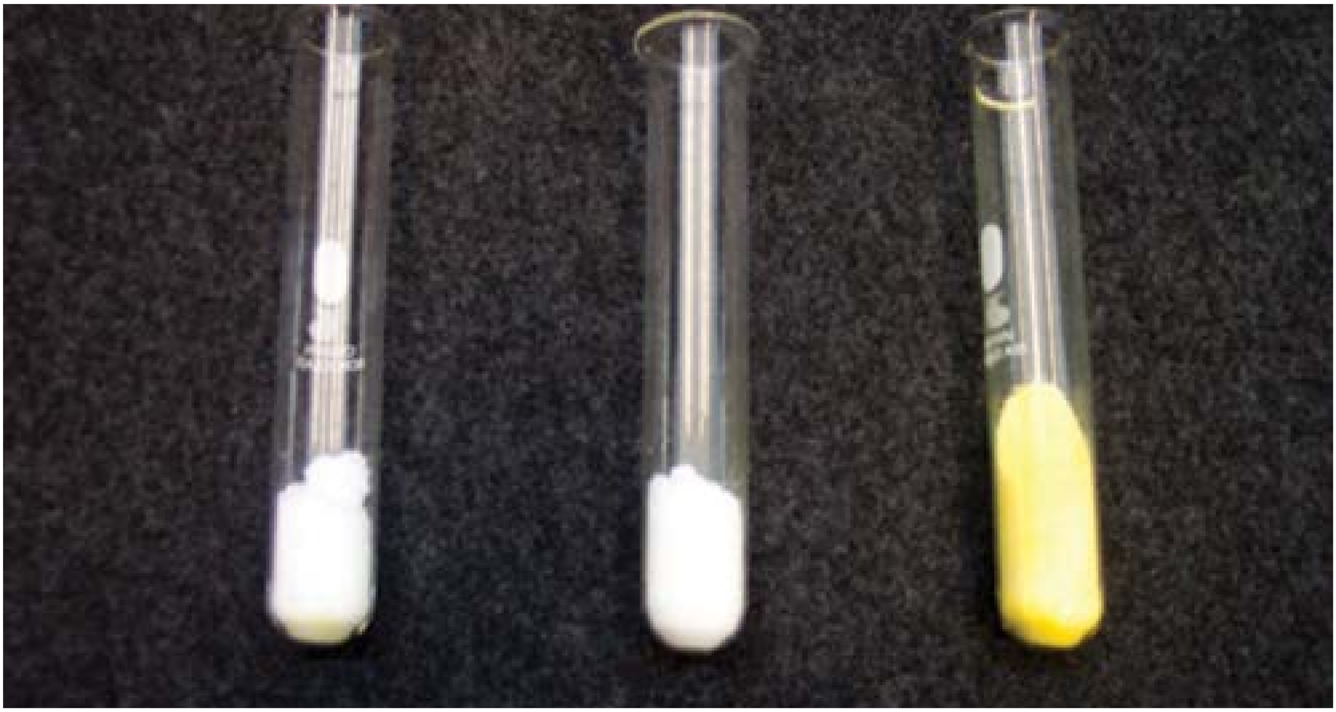


Figure 5. Reactants and product of this reaction.

The mixing of two solids to produce chemical reaction is unusual, as this reaction is normally done by mixing lead nitrate solution and potassium iodide solution. Using solids is more effective demonstration method. It also emphasises that collision is needed for reactions to occur.

Students will observe in the first instance there was only physical change since solid carbon dioxide turned into gas, whereas in the second example, a new substance with different colour was formed with no white powder apparent. This means that both potassium iodide and lead nitrate have converted to a new substance.

Learning Outcomes:

- Students should be able to distinguish between physical and chemical changes.
- Students should be able to interpret what they observed and write balanced equations from the Observations and include physical states for all reactants and products.

Chemical Disposal:

Any leftover dry ice should be placed in the esky with a loose fitting lid. Lead nitrate and lead iodide waste should be collected in a dedicated toxics waste bin.

DEMONSTRATION 2: Visualizing Avogadro's number

Figure 1. Equipment needed for this demonstration.

Concepts:

- Avogadro's number
- What is a mole and why chemists use it?
- The relationship between moles and mass

Safety:

Wear safety glasses and gloves when measuring out one mole mass of aluminium and copper sulphate pentahydrate.

Equipment:

- One mole of a variety of elements and/or compounds, each in a suitable, sealed container
  Figure 1 shows examples of one mole of different substances

Preparation:

Weigh out one mole of a variety of elements and compounds and place each into a sealed container. Label each container with the element's or compound's name and its molecular mass.

Demonstration Instructions:

1. Show the class the amount of one mole of each element/compound (don't forget to point out the molecular mass of each element and compound).
2. Explain to students that a mole is just a number, just like dozen of eggs means 12 eggs, a mole of eggs would be 6.02×10^{23} eggs. Now although it is possible to pick up just one egg and weigh it, it is impossible to pick up one atom and weigh it, because we do not have the instruments sensitive enough to do that, so when we want to work with atoms we have to use large numbers of them, otherwise they are too small to weigh out individually.
3. Mention a number of analogies to describe the size of one mole to help students comprehend the size of this number, for example:
   - 1 mole of rice would cover the whole of Australia to about 1 km deep.
   - Approximately one mole is the number of millilitres of water in the Pacific Ocean.
   - 1 mole of marbles, each 2 cm in diameter, would form a mountain 116 times higher than Mount Everest, and the base of it would be slightly larger than the area of the USA.
   - 1 mole of oranges would form a sphere the size of the Earth.

Observations:

- Students see a measurable unit (mole) of commonly used chemicals.
- Analogies for a mole are given using examples that students can identify with.

Learning Outcomes:

- Students should be able to understand that a mole is just a number, like a dozen, which is more realistic to work with when dealing with atoms.
- Students should be able to appreciate the size of a mole and at therefore the size of an atom.
- Students should be able to understand the relationship between mole and molar mass.

Disposal of Chemicals:

Elements and compounds in sealed containers with appropriate labels can be stored for future use – refer to MSDS forms for storage requirements.

DEMONSTRATION 3: Reacting magnesium with oxygen gas

Concepts:

- Characteristics of a chemical change
- Identify products of a reaction
- Balancing chemical equations

Safety:

- Safety glasses MUST be worn at all times
- DO NOT look directly at the light produced by the magnesium
- Work on a heat-proof mat when using open flames
- Turn off gas when not in use

Equipment:

- safety glasses
- heat-proof mat
- metal tongs
- portable Bunsen burner or small gas torch
- matches
- magnesium ribbon strips

Figure 1. Equipment needed for this demonstration.

Preparation:

Confirm beforehand that the portable Bunsen burner is working properly. Ensure smoke detectors have been temporarily de-activated prior to conducting this demonstration. Prepare small strips of magnesium and remove any oxide layer (use sand paper) formed on the magnesium prior to burning.

Demonstration Instructions:

1. Place the portable Bunsen burner on top of the heat-proof mat. Turn on the gas and light the burner. Make sure that you have a blue-coned flame.
2. Using metal tongs, pick up a piece of magnesium ribbon and hold it inside the hottest part of the flame. Wait until the magnesium starts to burn then take it out of the flame. Please make sure you tell students NOT TO look directly at the light produced by the magnesium.
3. Drop the burning magnesium ribbon onto the heat-proof mat.

Observations:

- The heated magnesium strip produces a bright white light (Figure 2).
- The magnesium changes from a silver metallic strip to a white powder.

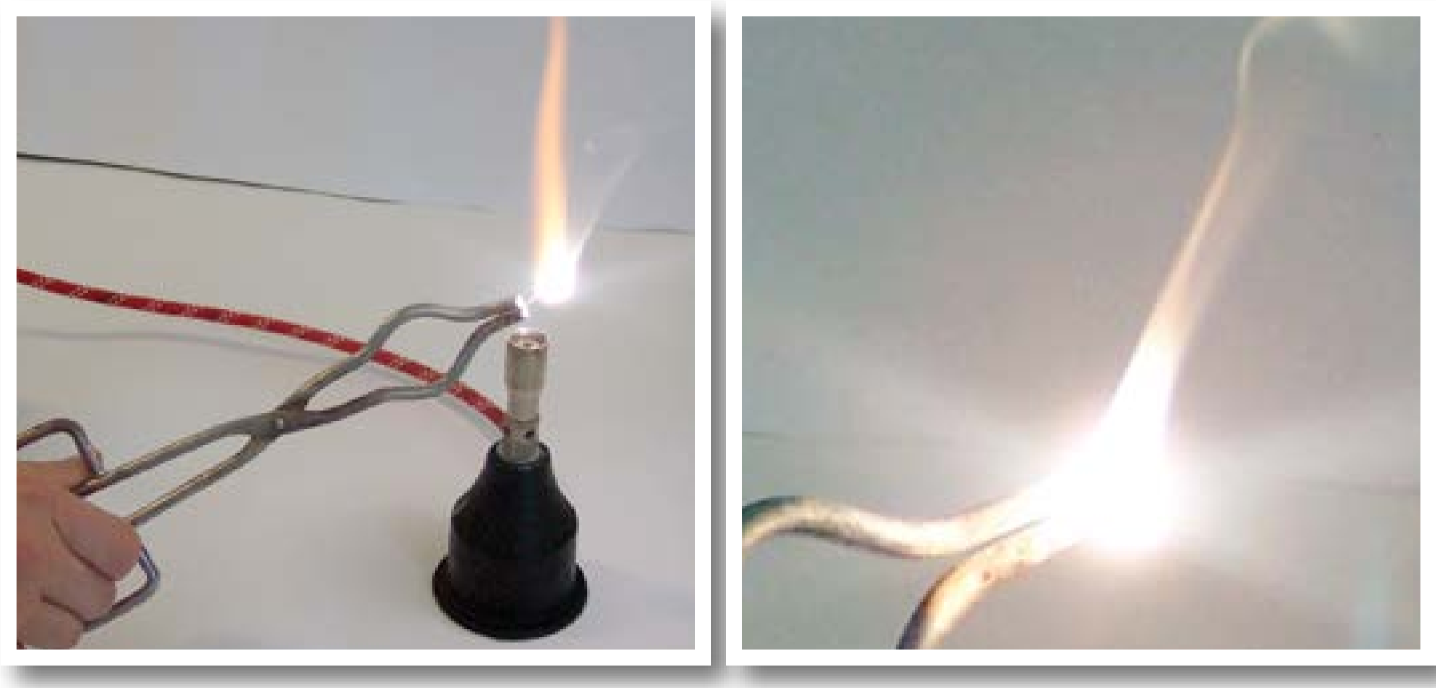


Figure 1. Left – place magnesium ribbon in the hottest part of the flame and hold till it lights up, right – close up view of the burning magnesium.

Chemical Equation:

$$\underset{\text{(silver metal)}}{2Mg_{(s)}} + \underset{\text{(colourless gas)}}{O_{2(g)}} \xrightarrow{\Delta} \underset{\text{(white powder)}}{2MgO_{(s)}}$$

Learning Outcomes:

- Students should be able to convert observations into a chemical equation.
- Students should be able to balance chemical equation.
- Students should identify states of matter and include those when writing equation.
- Students should be aware that products of a chemical reaction do not look like the reactants.

Disposal of Chemicals:

All waste solids should be placed into a laboratory bin when cool.

DEMONSTRATION 4: Reaction between sodium and water

Concepts:

- Characteristics of a chemical change
- Converting observations into chemical equations
- Identifying products of a reaction
- Balancing chemical equations

Safety:

- Safety glasses MUST be worn at all times
- Tweezers MUST be used when handling sodium
- Take only one piece of sodium (pea size) at a time out of the paraffin oil it is stored in
- Observe from a distance. Do not stand too close while the reaction is taking place

Equipment:

- safety glasses
- overhead projector
- large glass bowl (pneumetic trough)
- tap water
- tweezers
- scalpel
- ceramic plate
- sodium metal in a container with paraffin oil
- phenolphthalein indicator solution

Preparation:

Cut three pea-size pieces of sodium metal and place them in paraffin oil in an enclosed container. Half-fill the large glass bowl with water.

Demonstration instructions:

1. Place glass bowl (pneumatic trough) with water on top of the overhead projector.
2. Place about five drops of phenolphthalein indicator into the water.
3. Using tweezers drop a small piece of sodium metal into water (Figure 2).

Observations:

- A vigorous reaction takes place upon dropping the sodium metal into the water.
- A pink colour is formed as the metal reacts with the water (Figure 3).
- A colourless gas is evolved which ignites and small yellow flame is produced (depends on the size of the sodium).

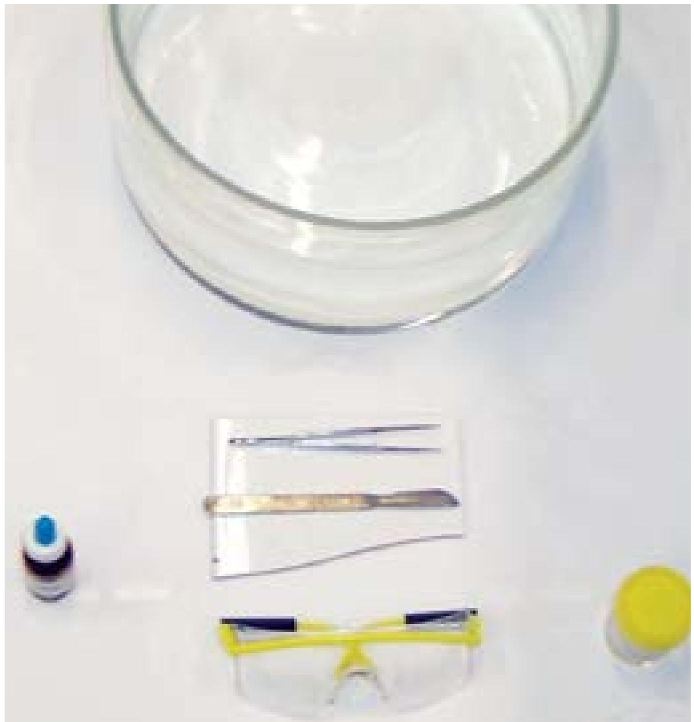


Figure 1. Equipment needed for this demonstration.

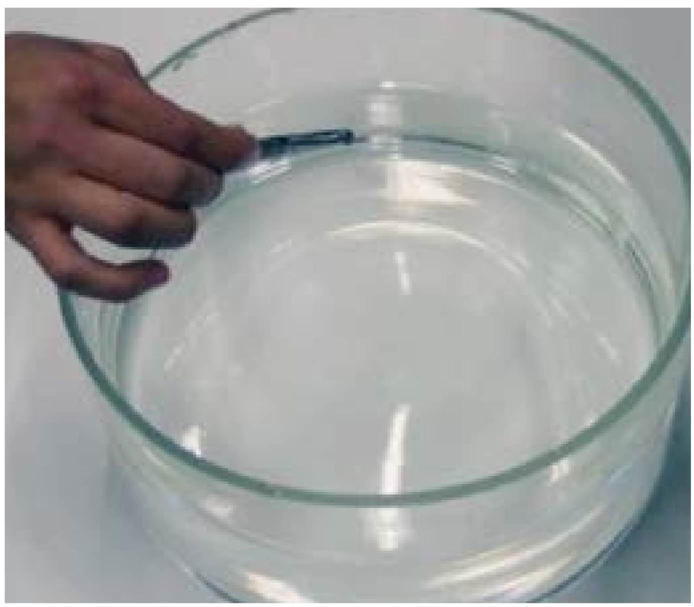


Figure 2. Using tweezers drop small piece of sodium metal into water.

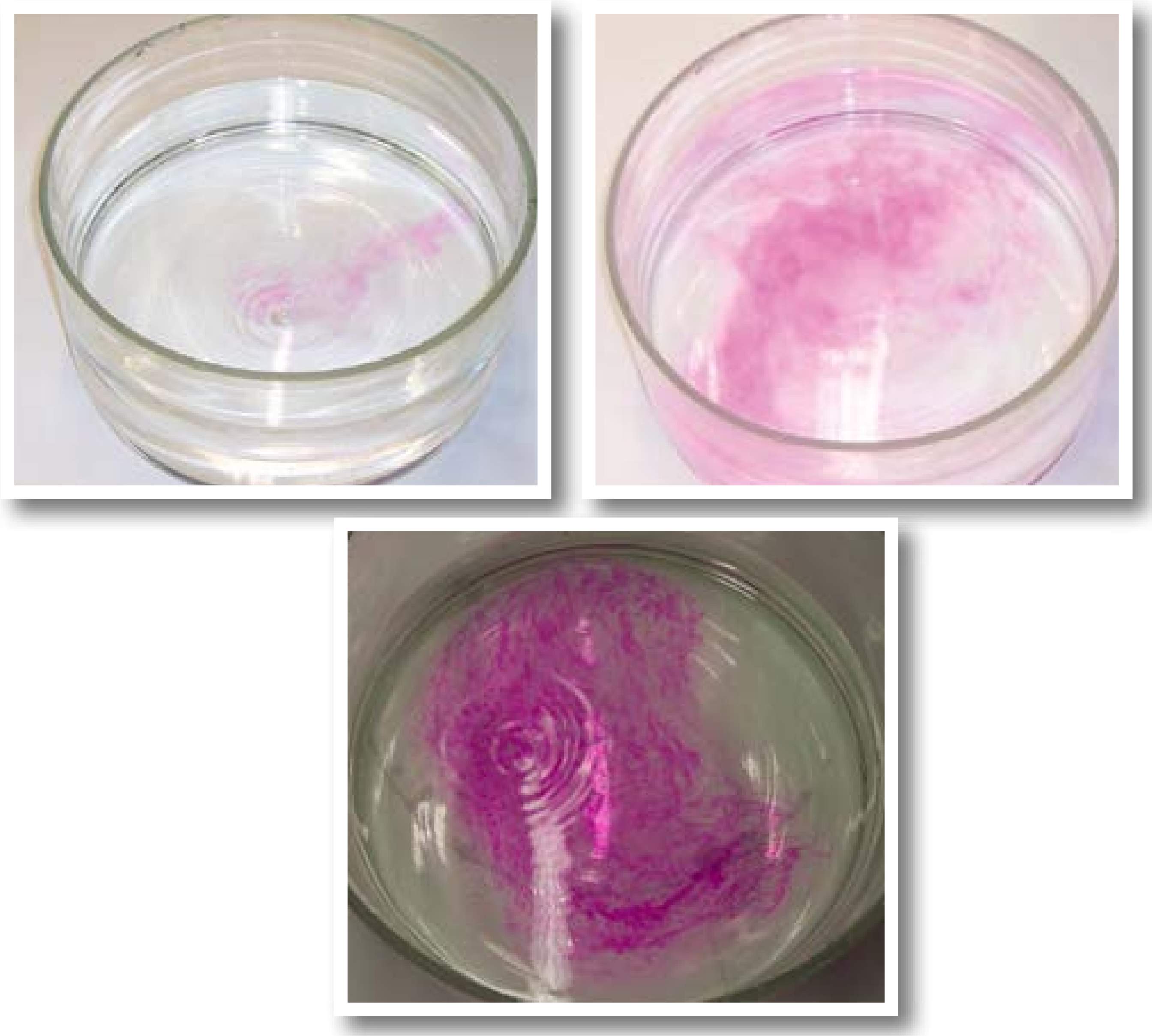


Figure 3. As soon as the sodium is dropped into water, the water starts to turn a pink colour, the colour is due to phenolphthalein indicator which turns pink in the presence of hydroxide ions, as the reaction proceeds more hydroxide ions are formed and more pink colour appears.

Chemical Equation:

$2Na_{(s)}$	+	$2H_2O_{(l)}$	$\rightarrow$	$2NaOH_{(aq)}$	+	$H_{2(g)}$
(silver solid)		(colourless liquid)		(pink solution due to inidicator)		(colourless gas)

Learning Outcomes:

- Students should gain practice in converting observations from a reaction into a chemical equation.
- Students should be able to balance chemical equations and identify states of matter.
- Students should understand the purpose of an indicator in this reaction and hence why the water turns a pink colour once the sodium metal is dropped in.

Disposal of Chemicals:

The left over alkaline solution should be washed down a laboratory sink with plenty of water without splashing. Ensure any leftover or unused sodium pieces are returned to the paraffin oil container. DO NOT flush ANY sodium pieces (no matter how small) down the sink.

DEMONSTRATION 5: Reacting hydrogen gas with oxygen gas in the air to produce water

Concepts:

- Explosive nature of hydrogen gas
- Characteristics of a chemical change
- Converting observations into chemical equation
- Identifying products of a reaction
- Balancing chemical equations

Safety:

- Safety glasses MUST be worn at all times
- Note that this reaction produces a large flame DO NOT conduct this reaction in a small room. Reaction may be done in a lecture theatre with plenty of overhead space and ventilation or alternatively outdoors away from flammables
- It is recommended that smoke and heat sensors are temporarily isolated to avoid an unnecessary evacuation – but note location of manual fire alarm and have a fire extinguisher ready in case of a fire
- Do not fill the balloon up too much with hydrogen as this will lead to a larger explosion. A small size balloon gives just as good as an effect and is safer and not as loud

Figure 1. Equipment needed for this demonstration.

Equipment:

- safety glasses
- balloons
- hydrogen gas
- several pieces of string (about 2 m each)
- a long stick with wax taper or wooden splint secured to the end
- matches

Preparation:

Inflate the balloons with hydrogen gas. If you are using a reaction of zinc and hydrochloric acid as your source of hydrogen gas, try not to let in any air into the balloon as the balloon may catch on fire and melt rather than explode. Tie a long piece of string to the end of each balloon.

Demonstration instructions:

1. Tie the end of the string around the leg of a chair or table. Make the string as long as possible, without allowing the balloon to touch the ceiling and so that you are able to reach it with the wax taper stick.
2. Light the wax taper.
3. Stand as far away as possible from the balloon and hold out the wax taper until it touches the balloon (Figure 3). WARN students to cover their ears.

Figure 2: Hydrogen balloon just before it explodes.

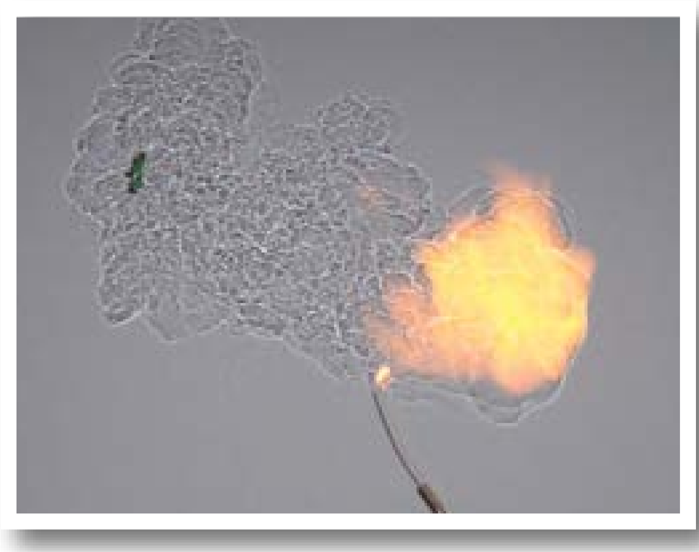


Figure 3: You can see the large amount of heat given off.

Observations:

- A very loud bang is heard.
- A large ball of flame is produced (Figure 3).
- Inspection of the remains of the balloon show small droplets of water formed inside the balloon (Figure 4).

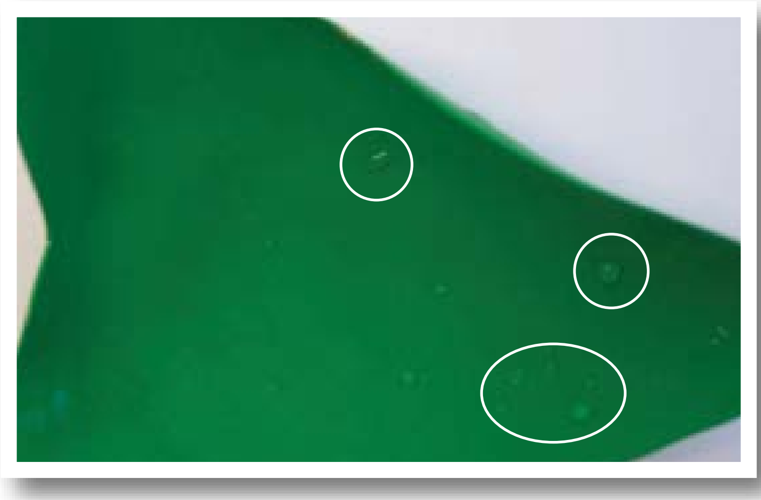


Figure 4: Water droplets left on the remains of the balloon.

Chemical Equation:

$$\underset{\text{(colourless gas)}}{2H_{2(g)}} + \underset{\text{(colourless gas)}}{O_{2(g)}} \xrightarrow{\Delta} \underset{\text{(colourless liquid)}}{2H_2O_{(l)}}$$

Learning Outcomes:

- Students should be able to write a balanced equation from observation and identify states of matter.
- Students should gain practice in converting observations from a reaction into a chemical equation.

Disposal of Chemicals:

Unexploded hydrogen balloons should be leaked out away from sparks.

Additional Information:

Also you can purchase some helium balloons ('non metallic') from any 'party shop' and then after you light the hydrogen balloon you can also light the helium balloon and demonstrate very effectively that helium unlike hydrogen gas is NOT explosive. Helium of course is inert and balloons of it will only pop as if filled with air.

DEMONSTRATION 6: Preparation and properties of oxygen gas

Concepts:

- Properties of oxygen gas
- How to prepare oxygen gas in a laboratory
- How to identify oxygen gas
- The role of a catalyst in a reaction
- Balancing chemical equations

Safety:

- Safety glasses MUST be worn at all times
- Take care when handling glass tubing, particularly when inserting tubing into stoppers or plastic tubing
- Do not place a lighted wooden splint inside the oxygen containing test tube

Figure 1. Equipment needed for this demonstration.

Equipment:

- safety glasses
- a large plastic container or 1L beaker
- 3 test tubes
- a delivery tube with a stopper on one end
- a clamp and stand
- spatula
- 10 mL measuring cylinder
- wooden splint and matches
- two rubber stoppers
- manganese (IV) dioxide (MnO_2)
- 20 mL of 10% hydrogen peroxide (H_2O_2)
- tap water

Figure 2. Set-up for this demonstration.

Preparation:

1. Fill the beaker or large plastic container ¾ full with tap water.
2. Completely fill two test tubes (up to the mouth of the test tube) with water. Place a rubber stopper over the tube mouth, invert and place the unsealed end under the surface of the water before removing the rubber stopped. The test tube should not contain any air.
3. Place the end of the delivery tube into the beaker.
4. Clamp the reaction tube.

Demonstration Instructions:

1. Place a small quantity (about a spatula full) of MnO_2 into a reaction tube and add 5 mL 10% H_2O_2 (Figure 3). Quickly replace the stopper assembly.
2. Allow a little gas to pass through the delivery tube (to displace the air) and then collect a test tube of oxygen to directing the tubing underneath one of the water filled test tubes (Figure 4). If the reaction stops add a further 5 mL 10% H_2O_2.
3. When the test tube is filled with oxygen, stopper it and remove it from the beaker of water (Figure 5).
4. Place a glowing, but not alight, wooden splint into the test tube (Figures 6 and 7).

Figure 3. Addition of MnO_2 .

Figure 4. Collecting oxygen gas.

Figure 5. Placing the rubber stopper.

Figure 6. Glowing splint.

Figure 7. Splint re-lighting inside O_2 filled test tube.

Observations:

- The reaction is quite vigorous, with the black MnO_2 foaming quickly (Figure 3).
- A colourless, odourless gas (O_2) is seen filling up the water filled test tubes (Figure 4).
- Oxygen is collected by downward displacement of water.
- A glowing splint re-lights when placed inside the test tube (Figure 7).

Chemical Equation:

$$2H_2O_{2(l)} \xrightarrow{MnO_{2\,(s)}} O_{2(g)} + 2H_2O_{(l)}$$

(colourless liquid) (black solid) (colourless gas) (colourless liquid)

Learning Outcomes:

- Students should be able to explain properties of oxygen gas.
- Students should be able to explain the role of a catalyst.
- Students should be able to write a balanced chemical equation for the preparation of oxygen gas.

Disposal of Chemicals:

Liquid waste should be flushed down the sink with plenty of water.

DEMONSTRATION 7: Chemiluminescence reaction

Concepts:

- Light as a form of energy
- Some reactions can produce energy in the form of light
- Chemicals in excited states

Safety:

- Safety glasses MUST be worn at all times
- Wear safety gloves when handling hydrogen peroxide

Equipment:

- 0.3 g luminol ($C_8H_7N_3O_2$)
- 36 g sodium bicarbonate ($NaHCO_3$)
- 6 g sodium carbonate (Na_2CO_3)
- 0.6 g copper sulphate –5-hydrate ($CuSO_4.5H_2O$)
- 1 L of water
- 500 mL of 10% hydrogen peroxide (H_2O_2)
- two 1 L beakers
- one 2 L beaker

Figure 1. Equipment needed for this demonstration.

Preparation:

In a 1 L beaker mix together the $C_8H_7N_3O_2$, $NaHCO_3$, Na_2CO_3, $CuSO_4.5H_2O$ and add approximately 1 L of water (heating may be required to dissolve luminol). In another 1 L beaker place 500mL of 10% H_2O_2.

Demonstration Instructions:

In a completely dark room mix together the two solutions by pouring them both at the same time into a 2 L beaker from some height. Allow the solutions to mix before they go into the beaker.

Observations:

1. As the two solutions are mixed a bright blue glow is seen, which only lasts for a few seconds.
2. After a few seconds the reaction stops glowing and a brown coloured solution is formed.
3. Lots of fizzing is observed.

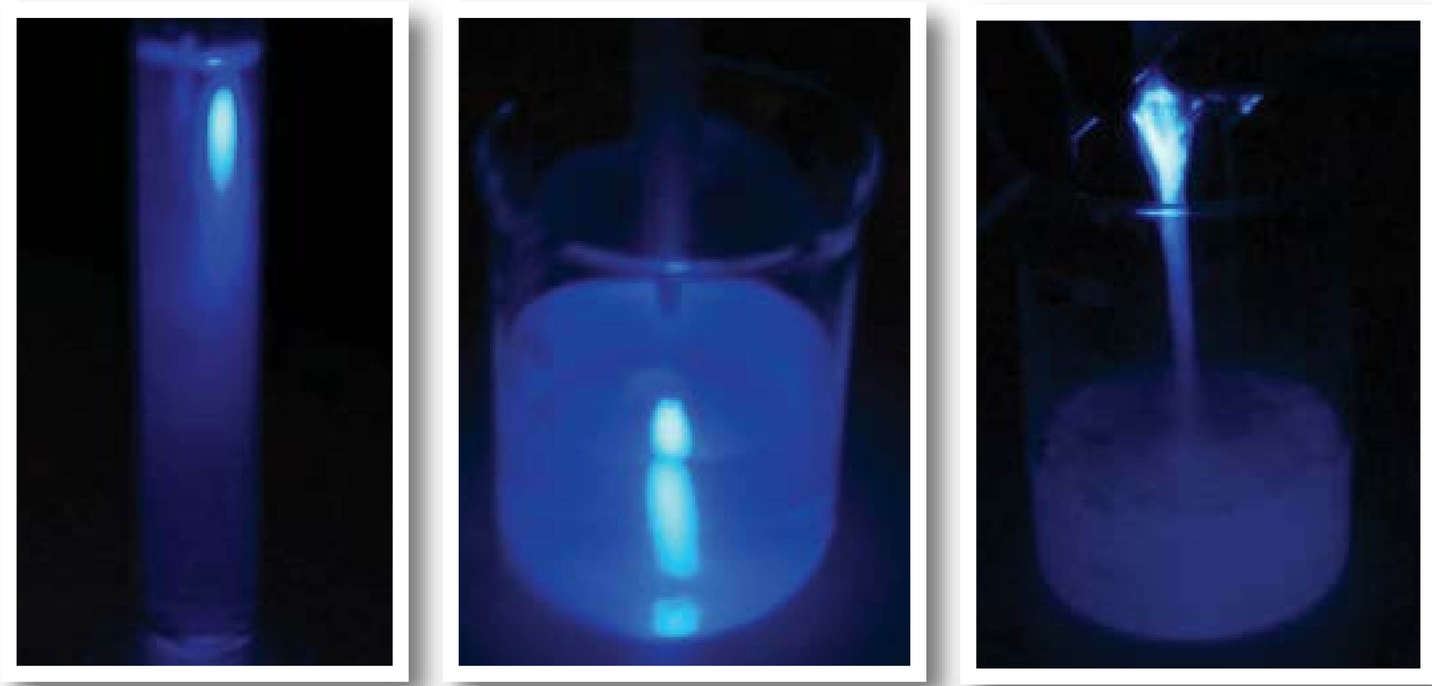
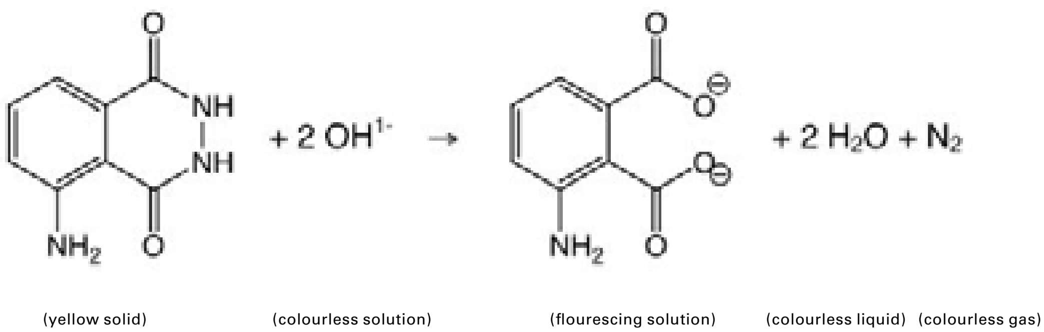


Figure 2. A bright blue light is seen as hydrogen peroxide is mixed with a buffered luminol solution.

Chemical Reaction:



Learning Outcomes:

- Students should understand that some chemical reactions emit energy in the form of light and these are called chemiluminescence reactions.
- Students should understand the concept of excited states of atoms.

Disposal of Chemicals:

All solutions should be flushed down a laboratory sink with plenty of water.

DEMONSTRATION 8: Memory metal

Concepts:

- Metallic bonding
- Crystalline structures
- Alloys

Safety:

- Be careful with hot water, use tongs when placing and removing memory metal from hot water

Equipment:

- 2 x 250 mL beakers
- Memory metal (Nitinol) in some configuration (can be obtained from Institute of Chemical Education at a cost of approx. $50)
- 200 mL of hot water (at least 60°C)
- 200 mL of cold water (less than 20°C)

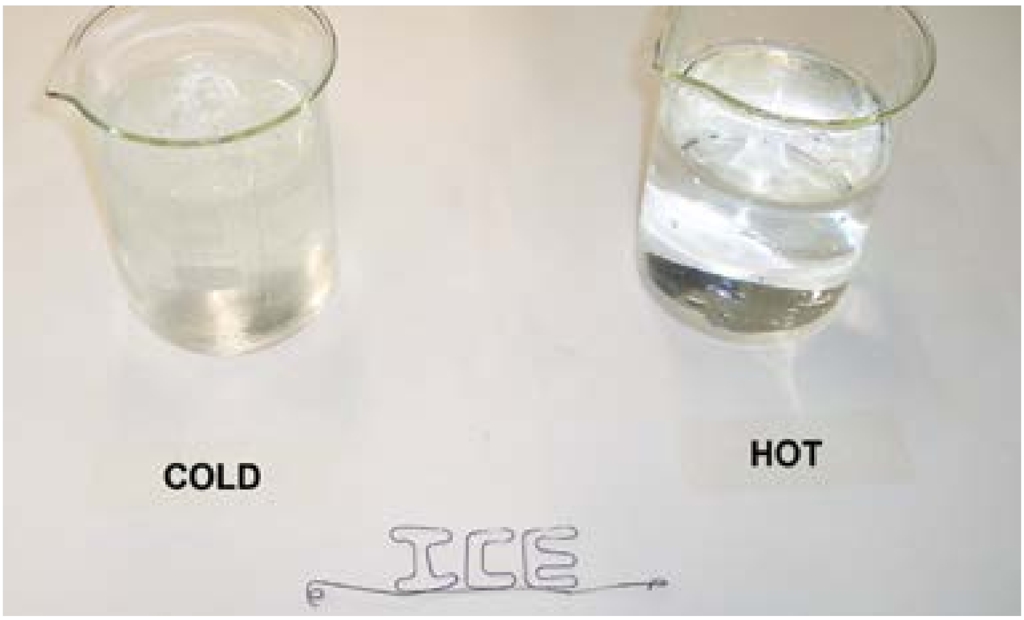


Figure 1. Equipment needed for this demonstration.

Preparation:

Fill one beaker with 200 mL cold water and the other beaker with 200 mL hot water (>60°C).

Demonstration Instructions:

1. Demonstrate the memory metal in it's original configuration, then stretch it out completely.
2. Place the stretched memory metal wire into the beaker with cold water (Figure 2).
3. Next place it into the beaker with hot water (Figure 3).

Observations:

When the stretched wire is placed in cold water, nothing happens, however, when it is placed into the hot water it immediately returns to its original shape. See the following website for detailed information explaining the theory and cool movies (http://jchemed.chem.wisc.edu/JCESoft/CCA/CCA2/MAIN/MEMORYM/CD2R1.HTM – last accessed Nov 2015).

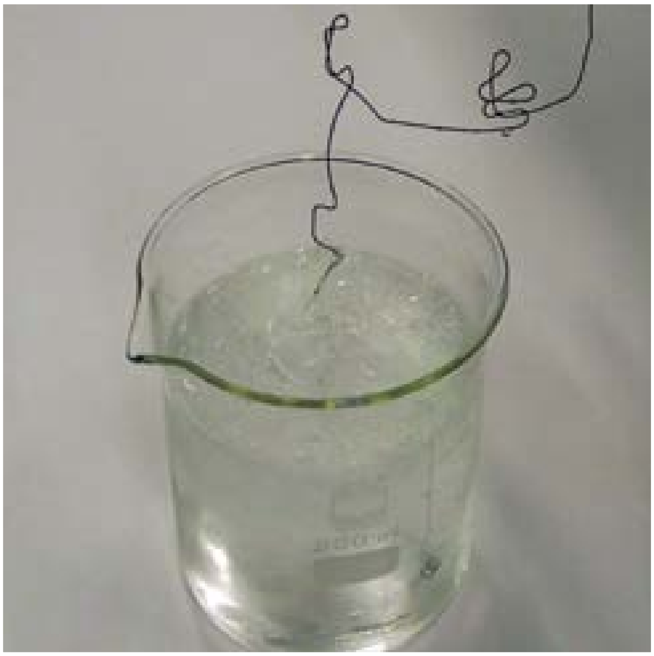


Figure 2. The memory metal is still deformed after being placed in cold water.

Figure 3. The memory metal reforms to its original shape after being placed in hot water.

Learning Outcomes:

- Students should understand what is an alloy and the difference in properties between pure metals and alloys formed from those metals.
- Students should be able to explain using metallic bonding theory why hot water was needed to reform the shape of the memory metal.

Disposal of Chemicals:

Nothing to dispose.

DEMONSTRATION 9: Decomposition of hydrogen peroxide

Concepts:

- Oxidising agents
- Decomposition reactions
- Reaction rates and catalysts
- Balancing equations
- Identifying products

Figure 1. Equipment needed for this demonstration.

Safety:

- Safety glasses MUST be worn at all times
- Wear rubber gloves when handling 30% hydrogen peroxide (H_2O_2) and when performing the demonstration

Equipment:

- 100 mL of 30% hydrogen peroxide (H_2O_2)
- pea-size amount of potassium permanganate ($KMnO_4$)
- 5 L conical flask
- spatula
- overhead projector
- safety shield (optional)

Preparation:

No prior preparation required.

Demonstration Instructions:

Add enough H_2O_2 to cover the bottom of the conical flask (about 30 mL into 5 L flask) – Figure 2. Place the flask on top of a projector and turn on the light. Then quickly add a pea-sized amount of $KMnO_4$ to the flask. (Figure 3).

Figure 2. Pour in enough hydrogen peroxide to cover the bottom of the flask.

Figure 3. Quickly add a small amount of potassium permanganate while the flask is sitting on top of the projector.

Observations:

1. When the H_2O_2 is poured into the flask, it looks like it is 'boiling' as it slowly starts to decompose to a colourless gas.
2. When $KMnO_4$ is added, suddenly all of the H_2O_2 is decomposed and due to heat being given off steam is formed (Figure 2).
3. At the end of the decomposition process, $KMnO_4$ is seen at the bottom of the flask (Figure 3).

Figure 4. The brown/purple stains on the inside of the flask is the left over $KMnO_4$.

Chemical Equation:

$$\underset{\text{(colourless liquid)}}{2H_2O_{2(l)}} \xrightarrow[\text{(purple solid)}]{KMnO_{4(s)}} \underset{\text{(colourless liquid)}}{2H_2O_{(l)}} + \underset{\text{(colourless gas)}}{O_{2(g)}}$$

Learning Outcomes:

- Students should appreciate the role of a catalyst in increasing the rate of reaction and not taking part in the reaction.
- Students should be able to understand decomposition reactions.
- Students should be able to write a balanced chemical equation for the decomposition of H_2O_2.

Disposal of Chemicals:

Rinse out the flask with water and flush it down the laboratory sink with plenty of water.

DEMONSTRATION 10: Nitrogen dioxide and dinitrogen tetroxide equilibrium

Concepts:

- Characteristics of dynamic equilibrium
- LeChatelier's Principle
- Temperature effect on equilibrium
- Predicting shifts in equilibrium

Safety:

- Safety glasses MUST be worn at all times

Equipment:

- 3 sealed glass tubes of nitrogen dioxide / dinitrogen tetroxide (NO_2/N_2O_4)
- three 2 L beakers
- ice
- approx. 1 L of boiling water

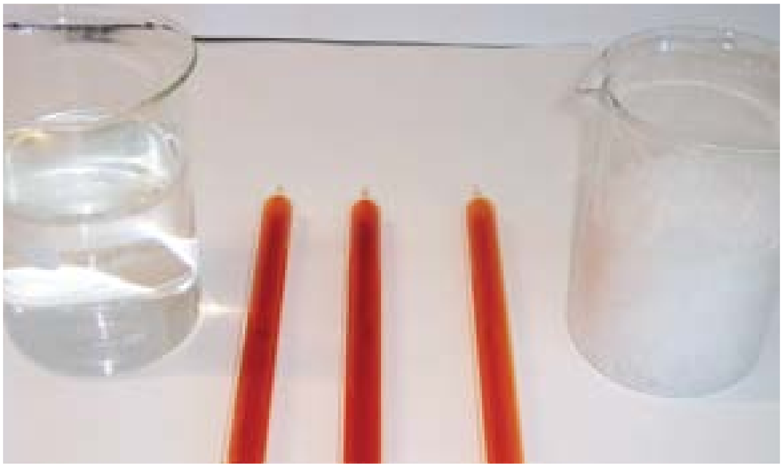


Figure 1. Equipment needed for this demonstration.

Preparation:

Fill one beaker half full of boiling water and the other beaker half full of ice.

Demonstration Instructions:

1. Place one NO_2 / N_2O_4 tube in the hot water, one into beaker with ice (try to pack the ice around the entire tube) and leave one tube at room temperature and place the third in the empty beaker (ie. room temperature).
2. After several minutes remove the tubes from the beakers and observe the colours (Figure 2).

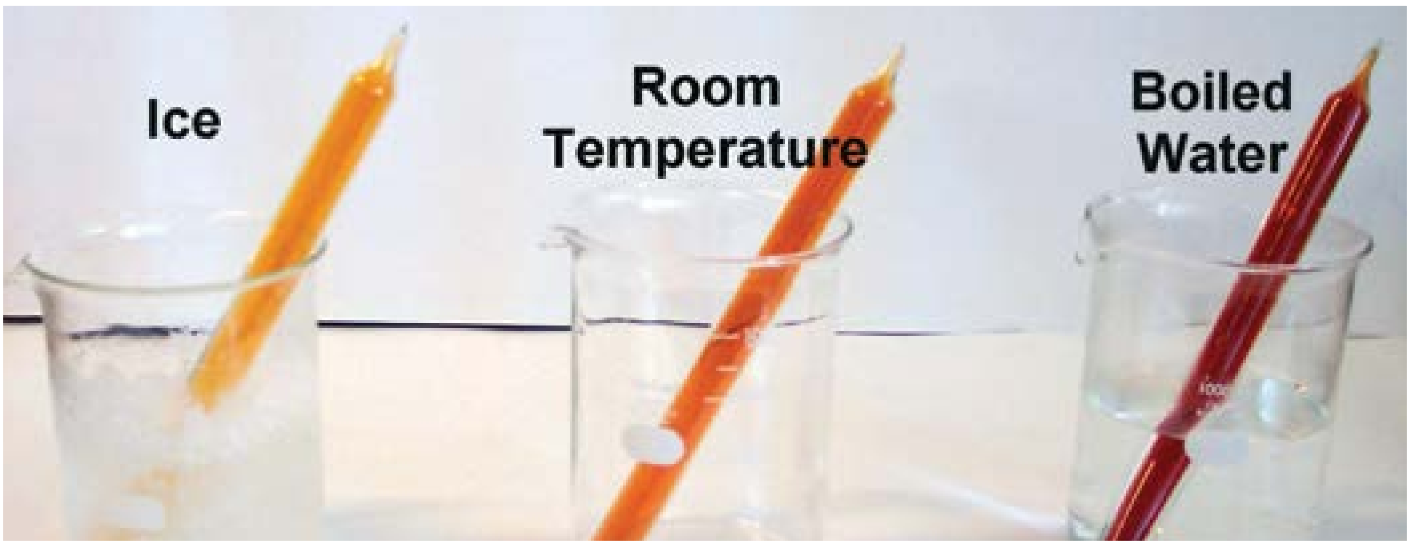


Figure 2. Comparison of NO_2 / N_2O_4 tubes after several minutes at different temperatures.

Observations:

1. The gas in the tube with hot water becomes very dark brown (Figures 2, 3).
2. The gas in the tube with ice becomes very light brown (Figures 2, 3).
3. The gas in the left tube in the empty beaker remains the same colour, brown (Figures 2, 3).

Figure 3. Comparison of NO_2 / N_2O_4 tubes after several minutes at different temperatures.

Figure 4. Close-up shot of tube in hot water, showing how there is more NO_2 being produced.

Chemical Equation:

$$\underset{\text{(brown gas)}}{2NO_{2(g)}} \leftrightarrow \underset{\text{(colourless gas)}}{N_2O_{4(g)}}$$

Learning Outcomes:

- Students should understand the concept of dynamic equilibrium.
- Students should be able to predict the shift in the equilibrium after subjecting the NO_2 / N_2O_4 equilibrium to different temperatures.

Disposal of Chemicals:

Nothing to dispose.

DEMONSTRATION 11: Sublimation of iodine

Concepts:

- Change of state from solid to gas
- States of matter
- Closed system dynamic equilibrium

Safety:

- Safety glasses MUST be worn at all times
- Wear safety gloves when handling iodine
- Minimise exposure to iodine fumes by conductubg this demonstration in a well ventilated environment

Equipment:

- 2 L measuring cylinder or 250mL beaker
- watch-glass
- iodine crystals
- A0 size white cardboard

Preparation:

No prior preparation required.

Figure 1. Equipment needed for this demonstration.

Demonstration Instructions:

1. Place some iodine crystals into the cylinder or beaker, enough to cover the base.
2. Quickly place the watch-glass on top of the cylinder or beaker.
3. Place the white carboard behind the measuring cylinder or beakers.

Observations:

1. While the formation of iodine vapour starts immediately it will take some time to see the purple vapour inside the cylinder, it may take up to about 15 min to see a considerable amount of iodine vapour.
2. Initially a pale purple gas will be seen in the cylinder. This is most obvious in a well-lit room with a white background.

Chemical Equation:

$$\underset{\text{(purple solid)}}{2I_{(s)}} \longleftrightarrow \underset{\text{(purple gas)}}{I_{2(g)}}$$

Figure 2. Iodine crystals sublime with time to form purple iodine gas.

Learning Outcomes:

- Students should be able to observe this enclosed system has dynamic equilibrium between solid and gas states.
- Students should be able to understand that iodine at atmospheric pressure will change directly from solid to gas state and this is called sublimation.
- Students should be able to write a balanced equation for this process.
- Students should be able to recognise this as a physical change.

Disposal of Chemicals:

Place left over solid iodine back into iodine bottle.

DEMONSTRATION 12: Oscillating Briggs-Rauscher reaction

Concepts:

- Rates of chemical reactions
- Types of chemical reactions

Safety:

- Safety glasses and safety gloves MUST be worn at all times
- Perform this demonstration in a well ventilated room

Equipment:

- 1 L beaker
- 500 mL beaker
- 500 mL measuring cylinder
- 100 mL measuring cylinder
- stirring rod
- 850 mL de-ionised water
- 13.0 g potassium iodide (KI)
- 1.0 g manganese (II) sulphate monohydrate ($MnSO_4.H_2O$)
- 5.0 g mlonic acid ($CH_2(COOH)_2$)
- 2.5 g Vitex
- 3 mL conc. sulphuric acid (H_2SO_4)
- 70 mL of 30% hydrogen peroxide (H_2O_2)

Figure 1. Equipment needed for this demonstration.

Preparation:

In a 1 L beaker dissolve KI, $MnSO_4.H_2O$, $CH_2(COOH)_2$, Vitex and concentrated H_2SO_4 in 850 mL de-ionised water.

Demonstration Instructions:

1. Measure out 300 mL of the dissolved solids and transfer to the 500 mL beaker.
2. Measure out 70 mL H_2O_2 and add to the dissolved solids.
3. Quickly transfer mixture to the 500 mL measuring cylinder.
4. Stir the solution in the measuring cylinder to create a vortex to increase the visual appeal of the reaction as the oscillation proceeds.

Observations:

1. The reaction initially turns from colourless to yellow (Figure 2).
2. The reaction then proceeds to a dark blue and back to colourless.
3. The reaction will oscillate through this colour change about 5 – 10 times before slowing down and stopping to display a dark blue colour (Figure 3).
4. Throughout this reaction colourless and odourless gas is formed.

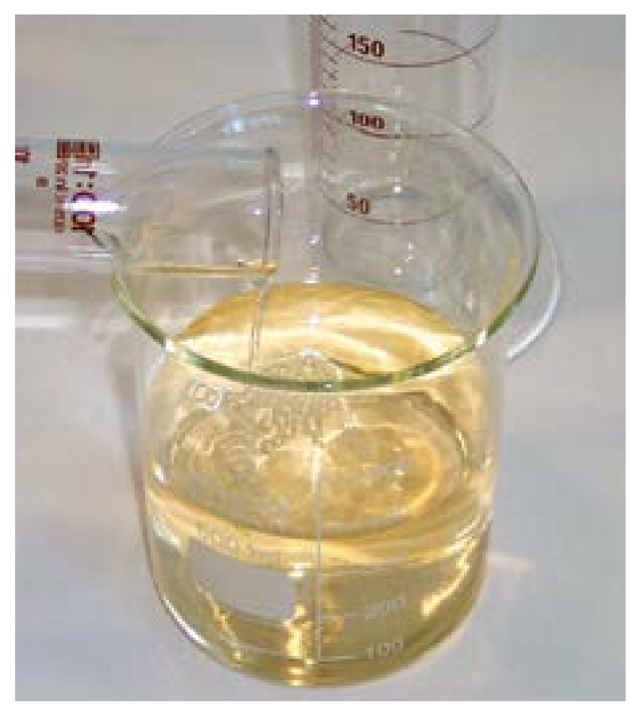


Figure 2. Adding H_2O_2 to the dissolved solids starts the reaction as seen by the colour change from colourless to yellow.

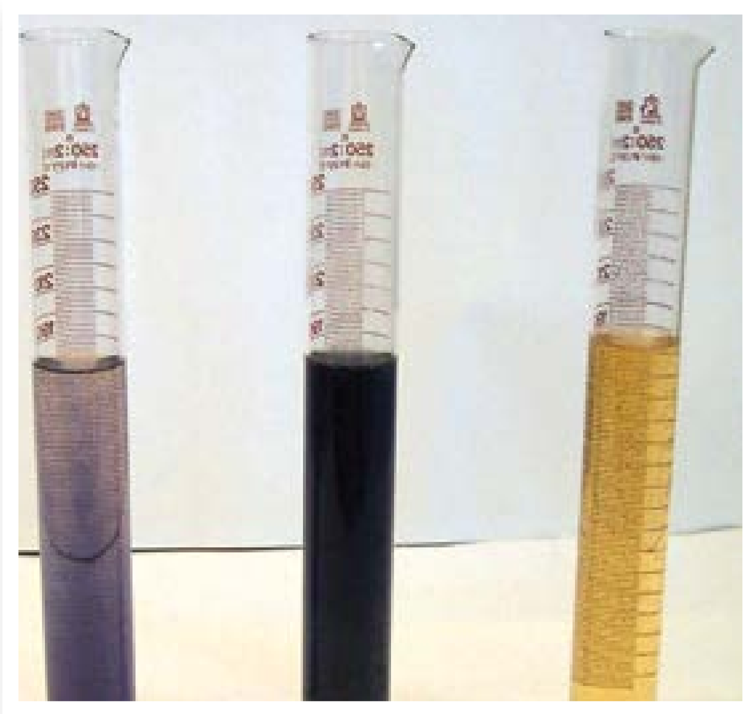


Figure 3. The reaction oscillates between yellow, dark blue and colourless.

Chemical Equations:

This reaction is quite complex and not fully understood. As I_2 is generated (equation ii) the blue colour is formed with Vitex and as it is reduced to I^-, the blue colour disappears. The system runs down as malonic acid is consumed.

(i) $H^+_{(aq)} + KIO_{3(aq)} \rightarrow HIO_{3(aq)} + K^+_{(aq)}$

(ii) $5H_2O_{2(l)} + 2HIO_{3(aq)} \xrightarrow{Mn^{2+}} I_{2(s)} + 6H_2O_{(l)} + 5O_{2(g)}$

(iii) $I_{2(s)} + CH_2(COOH)_{2(aq)} \longrightarrow ICH(COOH)_{2(aq)} + I^-_{(aq)} + H^+_{(aq)}$

(iv) $I_{2(s)} + ICH(COOH)_{2(aq)} \longrightarrow I_2C(COOH)_{2(aq)} + I^-_{(aq)} + H^+_{(aq)}$

(v) $5H_2O_2(l) + I_{2(s)} \longrightarrow 2HIO_{3(aq)} + 4H_2O_{(l)}$

(vi) $HIO_{(aq)} + H_2O_{2(l)} \longrightarrow I^-_{(aq)} + O_{2(g)} + H^+_{(aq)} + H_2O_{(l)}$

Learning Outcomes:

- Students should be able to understand that chemical reactions have different rates.
- Students should be able to recognise hydrogen peroxide as an oxidising agent.

Disposal of Chemicals:

This reaction produces elemental iodine, I_2, which should be reduced to iodide ions (I^-) before disposal. Therefore, inside a fumehood add sodium thiosulfate crystals until the mixture becomes colourless. When it cools, it may be flushed down the laboratory drain with plenty of water.

DEMONSTRATION 13: Neutralisation reaction

Concepts:

- Chemical properties of acids and bases
- pH indicators
- Acid-base reactions producing carbon dioxide gas

Safety:

- Safety glasses MUST be worn at all times
- Handle all chemicals with care

Equipment:

- 1 L measuring cylinder
- 100 mL water
- 2 table spoons of laundry detergent
- 4 table spoons of sodium bicarbonate ($NaHCO_3$)
- 400 mL beaker
- 200 mL vinegar
- 3 mL bromophenol blue indicator
- a large tray to catch any spills

Figure 1. Equipment needed for this demonstration.

Preparation:

In the 1 L measuring cylinder add the water, detergent and $NaHCO_3$ and in the beaker mix the vinegar with the indicator.

Demonstration Instructions:

Quickly pour the contents of the beaker into the cylinder (Figures 2 and 3).

Figure 2. Adding the vinegar.

Figure 3. Mixing the vinegar and sodium hydrogen-carbonate causes a colour change due to the increasing pH and the presence of universal indicator.

Figure 4. Production of CO_2 and the presence of detergent produces a foam that spills over the walls of the cylinder.

Observations:

- A thick foam is produced (Figure 2).
- When the vinegar is added the solution in the cylinder changes colour to blue/purple (Figure 3 and 4).

Figure 5. Close up of Figure 4.

Chemical Equation:

$$\underset{\text{(white solid)}}{NaHCO_{3(s)}} + \underset{\text{(colourless solution)}}{CH_3COOH_{(aq)}} \rightarrow \underset{\text{(colourless solution)}}{CH_3COONa_{(aq)}} + \underset{\text{(colourless liquid)}}{H_2O_{(l)}} + \underset{\text{(colourless gas)}}{CO_{2(g)}}$$

Learning Outcomes:

- Students should be able to predict the products of a reaction between an acid and bicarbonate.
- Students should be able to explain the reason for the colour change.
- Students should be able to write a balanced chemical equation for this reaction.

Disposal of Chemicals:

Dispose of all waste down a laboratory sink and flush down with plenty of water.

DEMONSTRATION 14: Carbonic acid and pH indicators

Concepts:

- Common pH indicator solutions
- pH range of those indicators

Safety:

- Safety glasses MUST be worn at all times
- Do not handle dry ice (solid carbon dioxide) with your bare hands – use either tongs or insulated gloves

Equipment:

- three 1000 mL measuring cylinders
- tap water
- universal indicator
- bromothymol blue indicator
- phenolphthalein solution
- 2 M sodium hydroxide (NaOH)
- 2 mL disposable pipette
- few pieces of dry ice
- tongs or insulated gloves

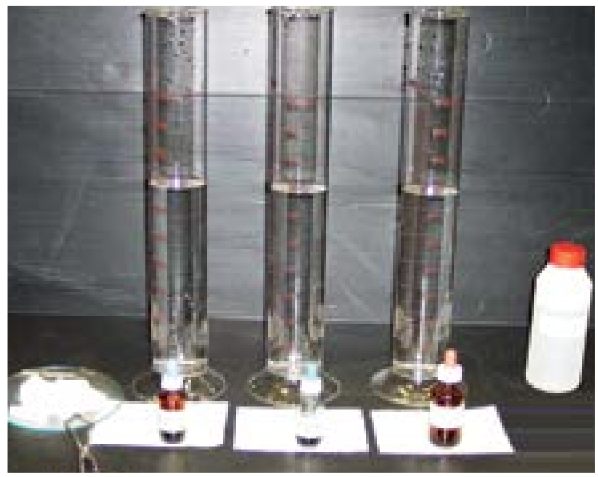


Figure 1. Equipment needed for this demonstration.

Preparation:

No prior preparation required.

Demonstration Instructions:

1. Add about 500 mL of tap water to each cylinder.
2. To the first cylinder add 10 drops of universal indicator, to the second cylinder add 10 drops of bromothymol blue and to the third cylinder add 10 drops of phenolphthalein.
3. Add a 2-3 drops of NaOH to each cylinder (Figure 2) then stir each solution to get a homogenous colour.
4. Using tongs, drop small pieces of dry ice into each cylinder and leave to stand (Figure 3).

Figure 2. NaOH and indicators are added to each cylinder.(A) universal; (B) bromothymol blue; (C) phenylphthalein indicator.

Figure 3. Dry ice is added to each cylinder.

Figure 4. While the dry ice appears to dissolve, the CO_2 forms carbonic acid.

Figure 5. The production of carbonic acid alters the pH, as seen by the change in colour of the indicators.

Figure 6. The pH continues to decrease, causing another colour change.

Figure 7. The last colour change.

Observations:

1. The dry ice bubbles and appears to 'dissolve' in the water.
2. As more CO_2 dissolves the colour of each solution with respect to the change in pH of each solution.
3. The pH drop is seen by the colour change in all three cylinders (Figures 5 – 7).
4. A mist forms when dry ice is added to each measuring cylinder.

Chemical Equation:

$$NaOH_{(aq)} + CO_{2(s)} \rightarrow NaHCO_{3(aq)}$$

(colourless solution) (white translucent solid) (colourless solution)

Learning Outcomes:

- Students should be able to identify the pH of each cylinder as indicated by the colour change.
- Students should be able to write a chemical equation for the reaction.

Disposal of Chemicals:

Dispose of all solutions down a laboratory sink and flush with plenty of water.

Figure 8. Dr Wajrak perfoming this demonstration.

DEMONSTRATION 15: Oxidation states of vanadium

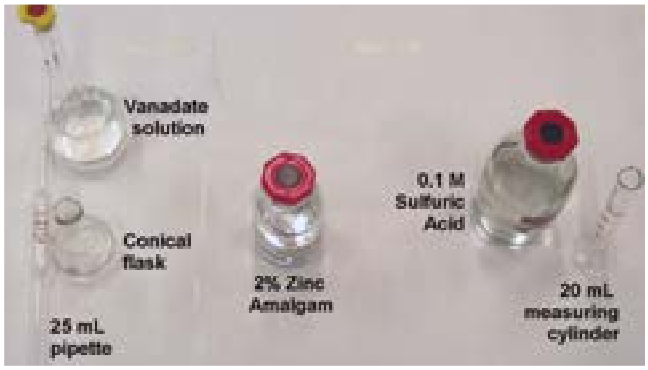


Figure 1. Equipment needed for this demonstration.

Concepts:

- Oxidation states and electron configuration
- Variable oxidation states

Safety:

- Safety glasses and gloves MUST be worn at all times
- Handle amalgam with great care, mercury is poisonous
- Gloves MUST be worn
- Use a plastic tray at all times to trap mercury if spilled

Equipment:

- tray to catch any spills
- 140 mL 0.1 sulphuric acid (M H_2SO_4)
- 30 mL of 2% zinc-mercury amalgam
- 1 g sodium sulphite (Na_2SO_3)
- stirring rod
- 20 mL measuring cylinder
- 250.00 mL volumetric flask
- hot plate
- 50 mL of ammonium vanadate solution (NH_4VO_3)
- 20 mL of 2M sulphuric acid (H_2SO_4)
- 20 mL of 2M sodium hydroxide (NaOH)
- two 250 mL stoppered bottles
- 100 mL measuring cylinder
- 25.0 mL pipette
- 250 mL conical flask

Preparation:

Prepare the ammonium vanadate solution prior to the demonstration. Dissolve about 2 g of NH_4VO_3 in about 20 mL of 2 M NaOH solution. Dilute to 250.00 mL in a volumetric flask. Then pipette 25.00 mL of this vanadate solution into an Erlenmeyer (conical flask). Add 20 mL of 0.1 M H_2SO_4 and approx. 1 g of Na_2SO_3. Boil the solution on a hot plate inside a fumehood until the excess sulphur dioxide (SO_2) is expelled (10-12 minutes should suffice).

Demonstration Instructions:

1. Mix 25.0 mL of ammonium vanadate solution, 20 mL 0.1 M H_2SO_4 and the amalgam in a stoppered bottle (Figure 2).
2. Shake the bottle vigorously for approximately 5 minutes – ensure the bottle is well sealed byholding your thumb firmly on the stopper while shaking (Figure 3).
3. Measure out 60 mL of ammonium vanadate solution into the second stoppered bottle.
4. Decant the solution from the first bottle into the second bottle.
5. Introduce a further 25.0 mL of ammonium vanadate and 20 mL 0.1 M H_2SO_4 into the second bottle.
6. Repeat step 2 onwards through all oxidation states (Figure 4).

Figure 2. Adding the vandate solution to the zinc amalgam.

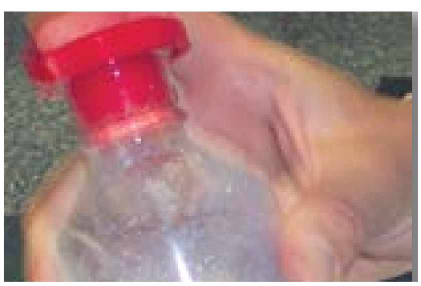


Figure 3. Shaking the mixture.

Figure 4. Final colour of the solution.

Observations:

1. When shaking the mixture vigorously the vanadium solution converts into different oxidation states.
2. Colours are associated with each oxidation state: yellow (V^{5+}), blue (V^{4+}), blue-green (V^{3+}) and purple (V^{2+}) (Figure 5). The V^{4+} appears to be green due to a mixture of the yellow and blue of V^{5+} and V^{4+}.

Chemical Equation:

This reaction is quite complex. The zinc is required for the reduction of V^{3+} due to the 'nascent' hydrogen it generates in reaction with the acid present.

The ions related to each vanadium species are: Vanadium (V) is $(VO_2)^+$, Vanadium (IV) is $(VO)^{2+}$, Vanadium (III) is V^{3+}, Vanadium (II) is V^{2+}.

The reactions are as follows:

$(VO_2)^+_{(aq)}$	+	$2H^+_{(aq)}$	+	e^-	$\longleftrightarrow$	$(VO)^{2+}_{(aq)}$	+	$H_2O_{(l)}$
$(VO)^{2+}_{(aq)}$	+	$2H^+_{(aq)}$	+	e^-	$\longleftrightarrow$	$V^{3+}_{(aq)}$	+	$H_2O_{(l)}$
$2H^+_{(aq)}$			+	$2e^-$	$\longleftrightarrow$	$H_{2\,(g)}$		
$V^{3+}_{(aq)}$			+	e^-	$\longleftrightarrow$	$V^{2+}_{(aq)}$		
$Zn^{2+}_{(aq)}$			+	$2e^-$	$\longleftrightarrow$	$Zn_{(s)}$		

Yellow Blue Blue-Green Purple

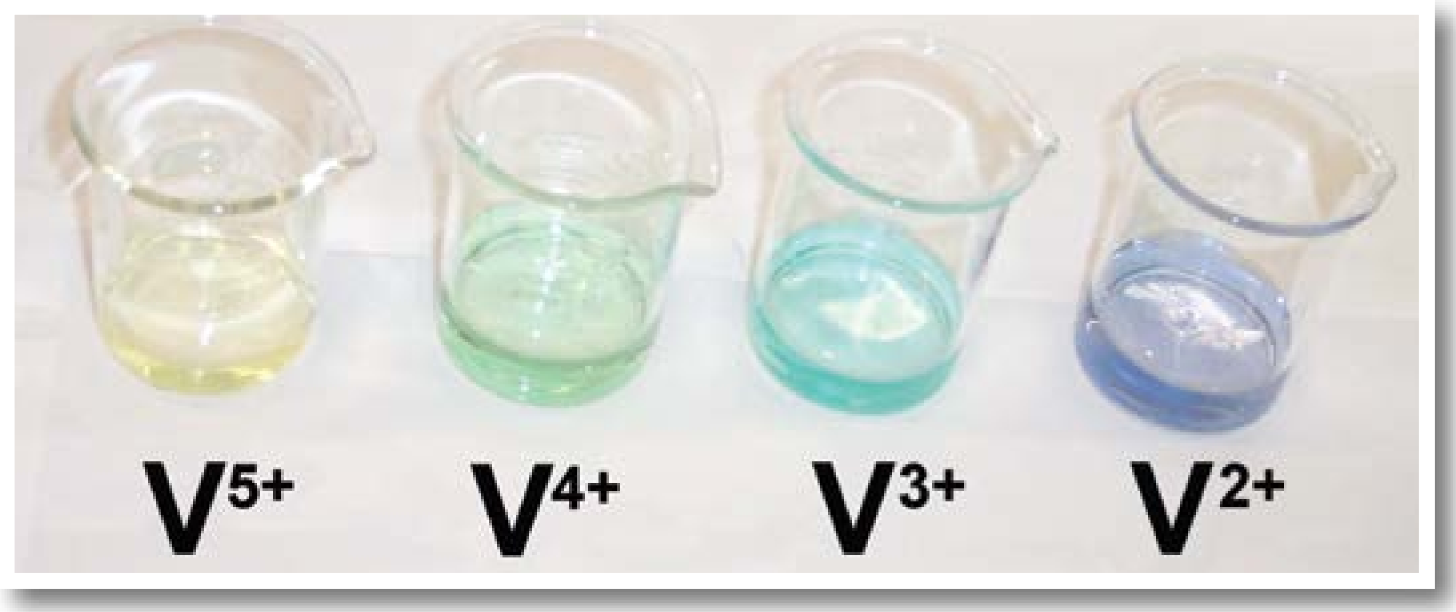


Figure 5. The colours of each oxidation state of vanadium.

Learning Outcomes:

- Students should be able to explain the colour changes at each stage of the process.
- Students should be able to recognise what species have been reduced and what species have been oxidized.
- Students should be able to identify all oxidation states of vanadium and their colours.
- Students should be able to write redox half-equations.

Disposal of Chemicals:

- Stopper the bottle that contains the zinc amalgam and make sure that the amalgam is left in 2 M H_2SO_4.
- Dispose of the vanadium solutions down a laboratory sink and flush down with plenty of water.

DEMONSTRATION 16: Zinc and copper sulfate redox reaction

Concepts:

- Spontaneous redox reactions
- Oxidation and reduction processes
- Balancing redox reactions

Safety:

- Safety glasses MUST be worn at all times
- Handle all chemicals with care

Equipment:

- two square zinc strips
- two x 200 mL beakers
- 150 mL of 0.1 M copper sulphate ($CuSO_4$)
- 150 mL of 0.1 M zinc sulphate ($ZnSO_4$)
- tongs

Preparation:

Cut out square zinc strips.

Figure 1. Equipment needed for this demonstration.

Demonstration Instructions:

1. Place a zinc strip into each beaker.
2. Pour in $CuSO_4$ solution into one beaker and $ZnSO_4$ solution into the other beaker, enough to cover the zinc plates (Figure 2.

Observations:

1. The Zn metal will react with the copper solution immediately and a brown precipitate will form on the top of the zinc metal. With time the blue solution of the copper sulphate will change to colourless (Figure 2).
2. Nothing happens to the second beaker where zinc strip is sitting in zinc sulphate solution.
3. After 30 minutes more brown precipitate deposits on the zinc in the copper sulphate solution and there is still no reaction in the second beaker (Figure 3).

Figure 2. Pouring $CuSO_4$ and $ZnSO_4$ solutions into beakers containing zinc plates.

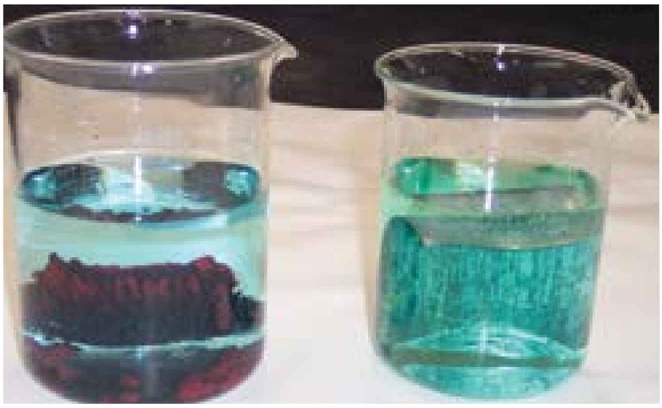


Figure 3. Cu metal deposits on the Zn strip in the $CuSO_4$ solution, but not in the $ZnSO_4$ solution.

Chemical Equations:

$Zn_{(s)}$	+	$CuSO_{4\,(aq)}$	→	$ZnSO_{4\,(aq)}$	+	$Cu_{(s)}$		E° = + 1.1V
(silver solid)		(blue solution)		(colourless solution)		(brown solid)		
$Zn_{(s)}$	+	$ZnSO_{4\,(aq)}$	→	No reaction				E° = - 1.1V
(silver solid)		(colourless solution)						

Learning Outcomes:

- Students should understand and be able to explain the reaction between Zn metal and $CuSO_4$.
- Students should understand and be able to explain why there is no reaction between Zn metal and $ZnSO_4$.
- Students should be able to write full equations for the redox reactions.
- Students should be able to predict if a reaction is spontaneous or not.
- Students should be able to calculate potential of redox reactions.

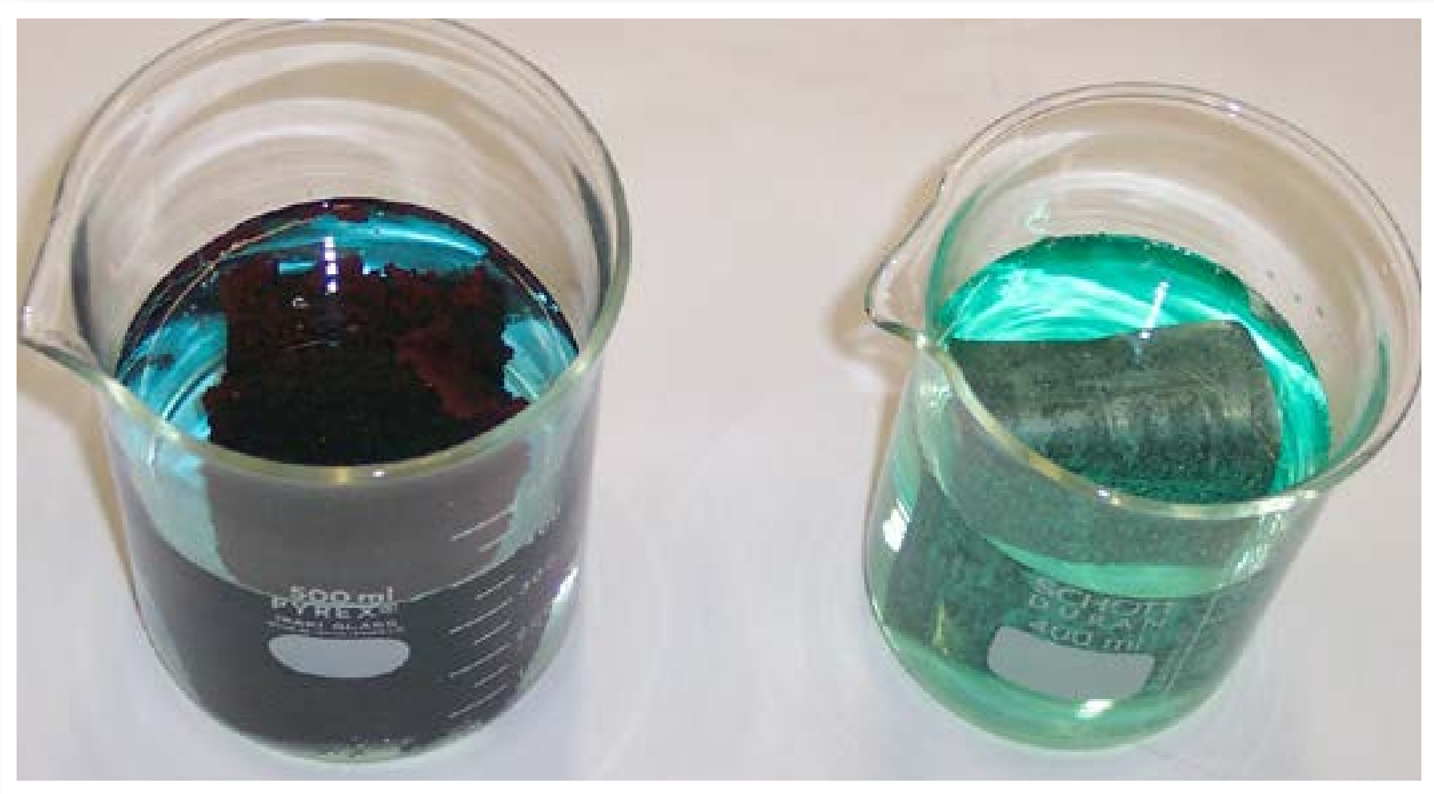


Figure 4. Top view of Figure 3.

Disposal of Chemicals:

- Dispose of liquid waste into a laboratory sink and flush down with plenty of water.
- Dispose of solid waste into a laboratory bin.

DEMONSTRATION 17: Optical activity of sugar

Concepts:

- Chiral and achiral molecules
- Isomerism
- Rotation of plane polarized light

Safety:

- Be careful with hotplate and avoid sugar solution spilling over onto the hotplate

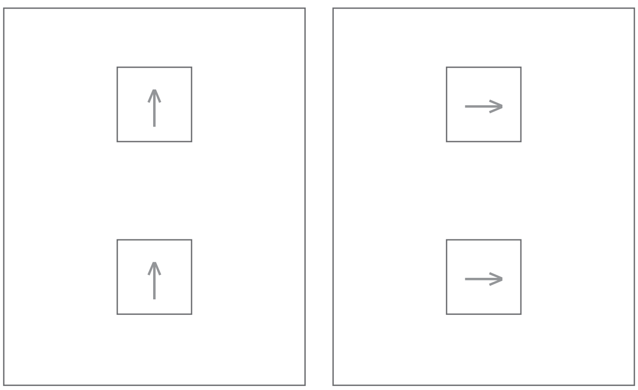
Equipment:

- overhead projector
- two pieces of cardboard about A4 size
- four squares of Polaroid film (about 4cm wide)
- sticky tape
- two 250 mL beakers
- 400 mL water
- white household sugar (sucrose)
- hot plate
- stirrer bar

Figure 1. Equipment needed for this demonstration.

Preparation:

1. Cut two squares in each piece of cardboard at equal distance apart. Secure the Polaroid film over the holes, with the Polaroid's grain direction on one sheet at 90° to the other sheet (see sketches below).



2. In one of the beakers dissolve as much sugar in 200 mL water until a syrup is formed – heating will be required (Figure 2).

Figure 2. Dissolving sugar.

Demonstration Instructions:

1. Place one of the Polaroid sheets on the overhead projector (Figure 3). Then place each beaker over a Polaroid square. Note that a square of light is projected through both liquids (Figure 4).

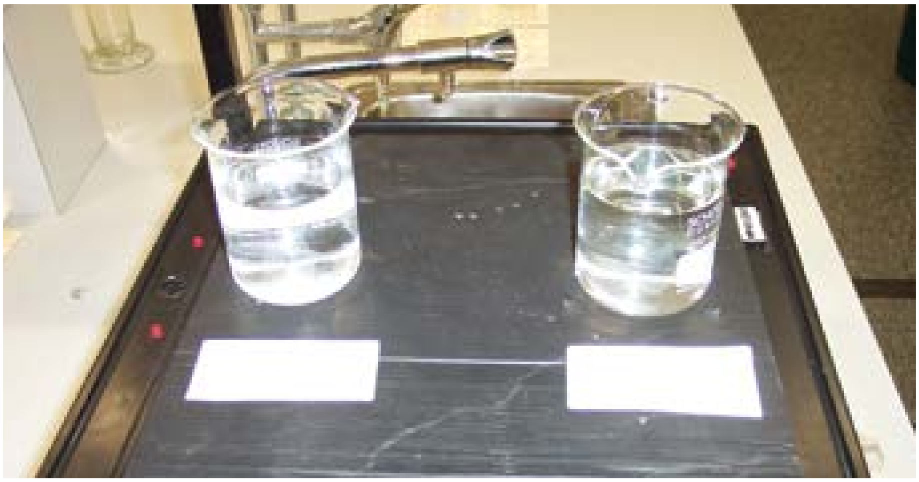


Figure 3. Setup for Step 1.

Figure 4. Projection of light through one layer of Polaroid film.

2. Then place the other Polaroid sheet on top of the beakers in line with the other sheet (see Figure 5). Note that now only one square of light coming from the beaker containing the sugar is being projected (Figure 6).

Figure 5. Setup for step 2.

Figure 6. Projection of light through two layers of Polaroid film. Some light is seen through the sugar solution.

Observations:

1. When the Polaroid sheets are in the same vertical position light comes through both solutions.
2. When one Polaroid sheet is in the horizontal position, only the sugar solution has the light coming through.

Learning Outcomes:

- Students should understand that sugar is optically active and therefore rotates plane of polarized light, where as water isn't optically active and cannot rotate plane of polarized light.

Disposal of Chemicals:

Cold sugar solution can be poured down laboratory sink and flushed with plenty of water.

DEMONSTRATION 18: Oxidation of alcohol using dichromate solution

Concepts:

- Oxidation of alcohols

Safety:

- Safety glasses MUST be worn at all times
- Wear gloves when handling potassium dichromate solution
- Keep flames away from alcohol

Equipment:

- overhead projector
- two crystallization dishes
- 3 mL spirits (e.g. Vodka)
- 6 mL acidified 0.1 M potassium dichromate ($K_2Cr_2O_7$)

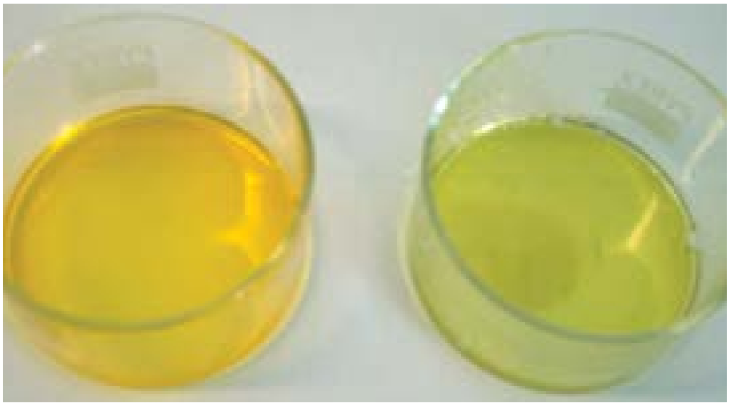


Figure 1. On the left is potassium dichromate solution, on the right some alcohol has been added to the dichromate solution.

Preparation:

To allow the reaction to be more obvious spike the spirit with 90% ethanol, but make sure you label the bottle that it is ONLY for laboratory use.

Demonstration Instructions:

1. Place both crystallization dishes on the overhead projector.
2. Pour half of the $K_2Cr_2O_7$ into each dish.
3. To one dish add 3 mL of the Vodka and into the other dish add 3mL of water.

Observations:

- After about 5 minutes the dish with the addition of spirits changes colour from yellow-orange to green (Figure 1).

Chemical Equation:

$$3CH_3CH_2OH_{(aq)} + 16H^+_{(aq)} + \underset{\text{(orange)}}{2Cr_2O_7{}^{2-}{}_{(aq)}} \rightarrow 3CH_3COOH_{(aq)} + \underset{\text{(green)}}{4Cr^{3+}{}_{(aq)}} + 11H_2O_{(l)}$$

Learning Outcomes:

- Students should be able to calculate oxidation numbers for each species in a redox reaction.
- Students should be able to understand the reaction of ethanol with potassium dichromate.
- Students should be able to write a balanced chemical equation to represent this reaction.
- Students should be able to predict the organic product when any alcohol is oxidized.
- Students should be able to explain how breathalysers work.

Disposal of Chemicals:

Dispose of $K_2Cr_2O_7$ / K_2CrO_4 solutions into a special waste beaker and follow protocols for disposal of this chemical. Flush all other chemicals down the laboratory sink with plenty of water.

DEMONSTRATION 19: Polarity of substances – lava lamp!

Figure 1. Addition of oil dye.

Concepts:

- Solubility of polar and non-polar substances
- Density of solutions

Safety:

- Safety glasses MUST be worn at all times
- Keep flames away from alcohol

Equipment:

- 500 mL measuring cylinder
- 5 mL vegetable oil
- 250 mL of water
- 5 ml of oil soluble dye (Sudan III works well)
- 250 mL of 100% ethanol
- plastic pipette

Preparation:

Add a small amount of Sudan III powder to a small amount of vegetable oil and mix. Pour water into cylinder and then carefully add ethanol to cylinder trying to reduce any mixing. The division of the two layers will not be readily observable from a distance

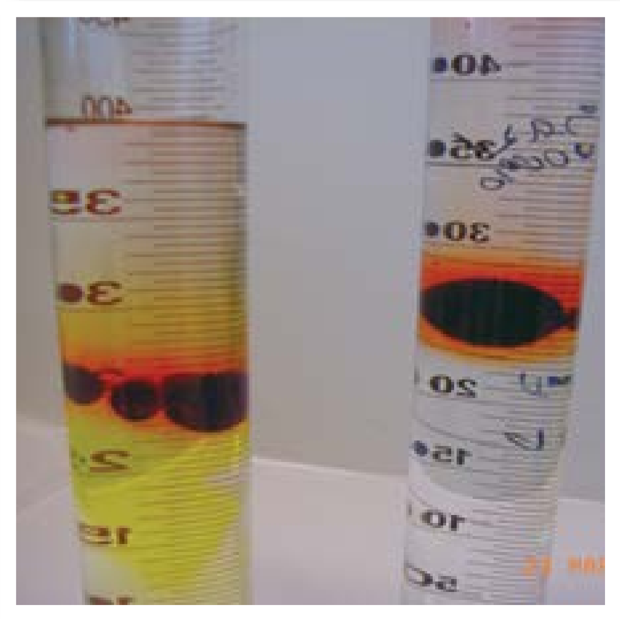


Figure 2. Suspended oil dye drop.

Demonstration Instructions:

Using plastic pipette apply colour oil drop wise to the cylinder (Figure 1).

Observations:

Oil moves quickly through the top ethanol layer but then gets suspended at the water interface (Figure 2).

Learning Outcomes:

- Students should be able to explain why the vegetable oil stops at the water interface.
- Students should be able to understand why ethanol is on top of the water.

Disposal of Chemicals:

Dye and ethanol should be disposed of according to your School's or University chemical disposal policy.

DEMONSTRATION 20: Silver mirror test

Concepts:

- Reducing sugars
- Reactions of monosaccharides, disaccharides and polysaccharides
- Reactions of aldehydes
- Avoid breathing in the ammonia fumes.

Safety:

- Safety glasses and rubber gloves MUST be worn at all times

Equipment:

- 150 mL of 0.1 M silver nitrate ($AgNO_3$)
- 2-4 mL of concentrated ammonium hydroxide (NH_4OH) solution
- 4g of glucose
- 250 mL round bottom flask
- stopper and pipette
- hot water bath

Figure 1. Equipment needed for this demonstration.

Preparation:

Prepare hot water bath (approx. 70^0 C)

Demonstration Instructions:

Place 150 mL of 0.1 M $AgNO_3$ into 250 mL round bottom flask, add 2-4 mL of concentrated NH_4OH solution and then add 4 g of glucose. Stopper the round bottom flask and swirl solution for approximately 30min. You can speed up the formation of the mirror by placing the flask in a hot water bath.

Figure 2. Reflective precipitate lines the inside of the flask.

Observations:

As the solution is swirled around inside the flask, a thin layer of the reflective precipitate is deposited which looks like a mirror.

Chemical Equation:

$$CH_2OH(CHOH)_4CHO_{(aq)} + 2Ag(NH_3)_{2(aq)} + 3OH^-_{(aq)} \rightarrow \underset{\text{(reflective solid)}}{2Ag_{(s)}} + CH_2OH(CHOH)_4CO_2^-{}_{(aq)} + 4NH_{3(aq)} + 2H_2O_{(l)}$$

Learning Outcomes:

- Students should be able to explain what a reducing sugar is.
- Students should be able to write a balanced chemical equation for this reaction.

Disposal of Chemicals:

Place any leftover silver nitrate into a special silver collection bottle for appropriate disposal.

DEMONSTRATION 21: Fingerprinting using iodine fuming

Concepts:

- Composition of eccrine sweat
- Amino acids form electron-donor-acceptor complexes with iodine

Safety:

- Safety glasses and gloves MUST be worn at all times
- DO NOT breathe in iodine fumes
- Perform this demonstration in a well ventilated area or fumehood.

Equipment:

- iodine crystals
- 1 L beaker or chromatography development tank
- clean A4 sheet of paper
- vaseline/petroleum jelly (optional)

Preparation:

Place some solid iodine at the bottom of a chromatography developing plastic tank (cylinder like) and cover, allow the iodine fumes to develop.

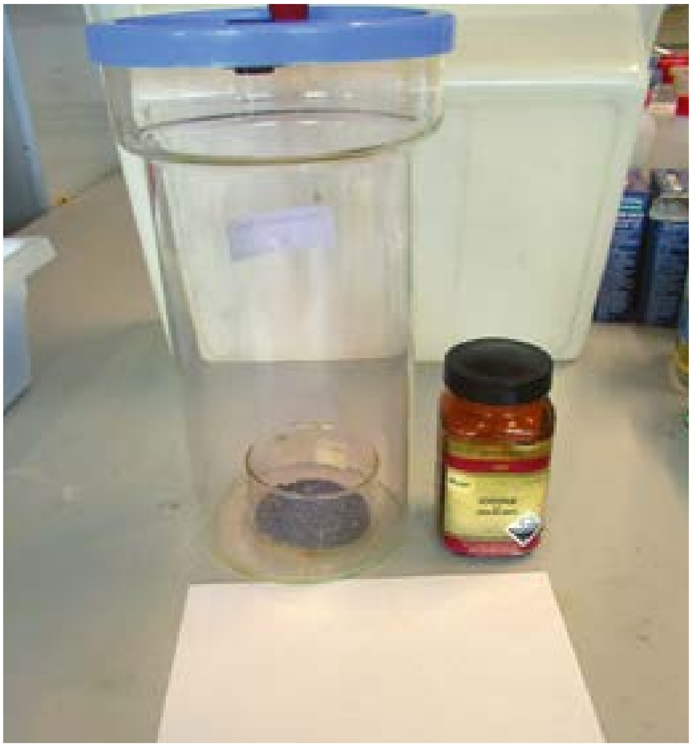


Figure 1. Equipment needed for this demonstration.

Demonstration Instructions:

Get a clean sheet of white paper, ask student to place his/her palm on the sheet of paper and then place paper inside the developing tank (sweaty palm gives best results), finger and palm print develops in few minutes.

Observations:

After a few minutes the imprint of the palm appears as a dark brown stain on the paper.

Learning Outcomes:

- Students should be able to understand that sweat contains amino acids.
- Students should be able to understand what is an electron-donor-acceptor complex.

Disposal of Chemicals:

Place any left over iodine back into the iodine bottle, and paper with fingerprint stain into the laboratory bin.

Figure 2. Palm print from iodine fuming.

DEMONSTRATION 22: Elephant's toothpaste (decomposition of hydrogen peroxide)

Concepts:

- Oxidising agent
- Decomposition reactions
- Reaction rates and catalysts
- Exothermic reactions

Safety:

- Safety glasses and rubber gloves MUST be worn at all times
- 30% hydrogen peroxide is highly corrosive, avoid contact with skin

Equipment:

- 500 mL measuring cylinder
- large washing up bowl
- garbage bag to act as a tablecloth
- scissors
- 200 mL of 30% hydrogen peroxide (H_2O_2)
- potassium iodide (KI) (solid) or 3 spatulas of KI dissolved in 20mL of water in a boiling tube
- 3-5 mL of green or blue food colouring
- a large squirt of good quality dishwashing liquid

Figure 1. Equipment needed for this demonstration.

Preparation:

Cut the garbage bag across the bottom and down one side and open out into a table cloth to be placed under the washing up bowl.

Demonstration Instructions:

1. Place the measuring cylinder in the washing up bowl.
2. Add 200 mL of the 30% H_2O_2 solution to the measuring cylinder.
3. Add the food colouring so that the solution can be seen by those at the back of the room. (The food colouring does not take part in the reaction).
4. Add a large squirt of the dishwashing liquid.
5. Add 3-4 spatula of solid KI to the H_2O_2 solution in one go.
6. Stand back.

Observations:

- The H_2O_2 is catalytically decomposed by the iodide ions and liberates oxygen gas that causes the foam to be formed.
- The reaction is seen to liberate a lot of steam as it is a highly exothermic reaction.
- Some brown colouration is seen in the foam formed from liberated iodine.

Figure 2. The reaction proceeds with time and more and more foam forms as more oxygen is released due to decomposition of hydrogen peroxide.

Chemical Equations:

$H_2O_{2(aq)} + I^-_{(aq)} \rightarrow H_2O_{(l)} + OI^-_{(aq)}$

$H_2O_{2(aq)} + OI^-_{(aq)} \rightarrow H_2O_{(l)} + O_{2(g)} + I^-_{(aq)}$

(The iodide ions speed up the reaction and are not used up and therefore they are a catalyst)

Net reaction $2H_2O_{2(l)} \rightarrow 2H_2O_{(l)} + O_{2(g)}$

Learning Outcomes

- Students should be able to define this reaction as a decomposition reaction.
- Students should understand what is an exothermic reaction.
- Students should understand the role and properties of a catalyst.

Chemical Disposal:

The foam should be allowed to collapse. The residual solution will contain unreacted hydrogen peroxide as well as iodine. It should be flushed down a sink using plenty of water (safety glasses and rubber gloves should be worn during disposal stage).

DEMONSTRATION 23: Methanol 'whoosh' bottle

Concepts:

- Flammability and volatility of alcohols

Safety:

- Safety glasses MUST be worn at all times by demonstrator and the audience
- Safety shield MUST be placed in front of the audience and the demonstrator
- This demonstration requires careful preparation, with strict adherence to the conditions as specified in 'additional information' on the next page
- Used water containers should NOT be used for storing drinking water

Figure 1. Equipment needed for this demonstration.

Equipment:

- one or more DRY polycarbonate 10 L water bottle
- rubber stopper or plastic cap (to fit the reaction vessel)
- beaker (250 mL), 1 for each alcohol used
- wooden splints
- meter ruler
- 40 mL of one of the following alcohols: methanol (CH_3OH), propan-1-ol ($CH_3CH_2CH_2OH$) or propan-2-ol ($CH_3CH_2OHCH_3$)

Preparation:

No prior preparation is required, however, repeat demonstrations will require additional dry reaction vessels.

Demonstration Instructions (see Figure 2):

1. Pour approximately 40 mL of the selected alcohol into a beaker and then transfer into the reaction vessel.
2. Insert the rubber stopper and roll the reaction vessel on its side for 10 seconds, to and fro, allowing the alcohol to vaporise and the vapour to fill the vessel. Do not warm the alcohol.
3. Pour surplus liquid alcohol back into the beaker, draining the vessel as completely as possible, and move the beaker away from any source of flame. Surplus liquid left in the vessel may ignite and set fire to the vessel as well.
4. Stand the reaction vessel securely inside the Safety screens and remove the stopper. Attach a wooden splint to the end of the metre rule or stick using adhesive tape, angling the splint so that when the metre rule is horizontal, the splint is sloping downwards. Light the wooden splint, and apply the lighted end of the splint to the open neck of the vessel. Do not lean over the screens to apply the ignition. It is dangerous to ignite by dropping a lighted match into the vessel when using ethanol or methanol.
   For both propanols, this method may be used providing the neck of the bottle is above head height.

Figure 2. Steps involved in setting up the 'whoosh' bottle demonstration.

Observations:

A mixture of alcohol and air in a large polycarbonate bottle is ignited. The resulting rapid combustion reaction, often accompanied by a dramatic 'whoosh' sound and blue flames, demonstrates the large amount of energy released in the combustion of alcohols.

Figure 3. Demonstration of the 'whoosh' bottle.

Learning Outcomes:

- Student should understand that simple alcohols are very volatile.
- Students should be able to understand the energy released during combustion of a flammable chemical.
- Students should be able to understand the dangers related to flames and alcohol.

Chemical Disposal:

- Let the reaction vessel dry for several days before using it again.
- Pour the left over alcohol back into the original glass bottle for reuse.

Additional Information:

- Select a safe, level place for the demonstration, with at least 2.5 m clearance above the top of the vessel to the ceiling above, and no flammable materials above it. If the laboratory bench does not allow for this, 4 stable laboratory stools supporting a large wooden tray may give sufficient clearance and stability.
- Set out the bottles containing the alcohols and the beakers at least 1 m away from the demonstration. No flames within 1 m. Students at least 4 m away.
- The experiment demonstrates dramatically just how much chemical energy is released from such a small quantity of fuel.
- The flame colour varies with the proportion of carbon in the alcohol molecule. With methanol and ethanol there is a very quick 'whoosh' sound and a blue flame shoots out of the bottle. With propan-1-ol and propan-2-ol, the sound is similar but the reaction is slightly slower, easier to observe, and blue and yellow flames may be observed 'dancing' in the bottle. The presence of water reduces the likelihood of dancing flames.
- A wide-ranging and up-to-date review of the production and use of alcohols for vehicle fuels, with links to a variety of related sites, can be found at: http://en.wikipedia.org/wiki/Alcohol_fuel (last accessed Nov 2013) http://www.practicalchemistry.org/experiments/the-whoosh-bottle-demonstration.240.EX.html

DEMONSTRATION 24: Iron extraction on a match head!

Concepts:

- Oxidation – reduction reaction
- Reduction of iron oxide with carbon to produce iron

Safety:

- Safety glasses MUST be worn at all times
- Be careful when using cigarette lighter

Equipment:

- cigarette lighter or box of matches (not safety matches)
- small amount of iron (III) oxide (enough to cover bottom of petri dish)
- small amount of sodium carbonate (enough to cover bottom of petri dish)
- three plastic petri dishes
- bar magnet (in either Glad®wrap or Ziploc® bag)
- de-ionised water
- heat-proof mat

Figure 1. Equipment needed for this demonstration.

Preparation:

Wrap magnet in Glad®wrap or Ziploc® bag.

Demonstration Instructions:

- Show that neither iron oxide nor sodium carbonate is magnetic. Take an unlit match moisten the head by dipping in water.
- Roll the match's head in some powdered iron(III) oxide and then into the sodium carbonate.
- Use the lighter to burn the match head.
- Crunch the match head onto a clean dry plastic petri dish.

Figure 2. Burning of the match-head.

Observations:

With the magnet underneath the petri dish move it under the ashes. Sufficient iron is produced to be moved by the magnet.

Chemical Equation:

$$\underset{\text{(rusty solid)}}{2Fe_2O_{3\,(s)}} + \underset{\text{(black solid)}}{3C_{(s)}} \rightarrow \underset{\text{(grey solid)}}{4Fe_{(s)}} + \underset{\text{(colourless gas)}}{3CO_{2(g)}}$$

Learning Outcomes:

Students should be able to understand that iron oxide is reduced by the carbon produced during the combustion.

Chemical Disposal:

Ensure the products are unlit and dispose of them in a laboratory bin.

Additional Information:

Putting iron oxide and sodium carbonate on petri dishes themselves may make this easier, because the iron oxide is reduced by the carbon/carbon monoxide formed when the match head is burnt. The carbon/carbon monoxide gets oxidised to carbon dioxide.

DEMONSTRATION 25: Polymorph – thermosetting polymer

Concepts:

- Structure of polymers
- Properties of thermosetting polymers

Safety:

- Under no circumstances should Polymorph be moulded around parts of the body, risking the danger of it hardening in position
- Be careful when handling polymorph once taken out of boiling water, polymorph will be very hot

Equipment:

- approximately 20 grams of polymorph polymer
- 250 mL beaker
- stirring rod
- kettle
- tap water

Preparation:

Boil water.

Demonstration Instructions:

1. Add approximately 20 g of polymorph to a beaker of boiling water (or at least over 65° C), stir with a glass rod till the granules all come together and are completely transparent.
2. Using a pair of tongs take the polymer out of the beaker and mould it to whatever shape you like.

Observations:

The material undergoes a change. As the material cools it will go white and will no longer be able to be shaped. The polymer may be reheated and shaped many times. The polymer is also biodegradable.

Learning Outcomes:

Students will be able to relate the structure of a polymer to its properties.

Chemical Disposal:

Thermosetting polymer is re-usable, so there is nothing to be disposed of.

Additional Information:

- Polymorph may be obtained from: http://www.mutr.co.uk/
- http://www.mutr.co.uk/ is the source of a great many interesting smart materials.
- There are now coloured pellets that can be blended into polymorph to give different colour to white polymorph upon shaping.

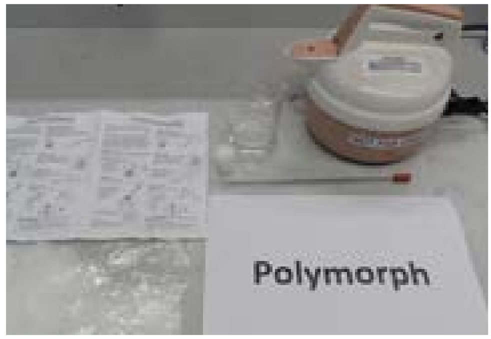


Figure 1. Equipment needed for this demonstration.

Figure 2. Stir the polymorph in hot water until it coagulates and forms a mould.

Figure 3. Polymorph moulded into the shape of a swan.

DEMONSTRATION 26: Non-burning money

Concepts:

- Flammability and volatility of alcohols

Safety:

- Safety glasses MUST be worn at all times
- Ethanol solution (50%) is flammable
- When conducting this experiment keep the burning note away from the beaker of ethanol

Equipment:

- non-plastic bank notes
- tongs
- 20 mL of 50% ethanol/water solution
- 250 mL beaker
- lighter or matches

Figure 1. Equipment needed for this demonstration.

Preparation:

In advance prepare a 50% ethanol/ water solution.

Demonstration Instructions:

1. Soak the currency in the alcohol/water mixture.
2. Hold in tongs and light the note with a lighter, but make sure it is AWAY from the stock solution of ethanol/ water solution.

Observations:

The bank note appears to be on fire, but it doesn't actually burn.

Figure 2. The ethanol soaked currency is set alight, but it doesn't burn.

Learning Outcomes:

The students should be able to understand the heat energy generated by the combustion is lower than that needed to burn the wet paper.

Chemical Disposal:

Pour the left over ethanol/water mixture into the original glass bottle for reuse.

Demonstration 27: The true reactivity of aluminium

Concepts:

- Aluminium foil is coated with an impervious aluminium oxide coating that masks the true reactivity of aluminium
- Aluminium being a reactive metal will react with dilute acids liberating hydrogen gas
- Exothermic reactions

Safety:

- Gloves and glasses MUST be worn at all times
- Mercury chloride is toxic, corrosive and dangerous for the environment
- Hydrochloric acid (2.0 M) is harmful
- Coke or Pepsi used must be marked as 'Lab use only-do not drink'

Equipment:

- tray
- 50cm of aluminium foil
- 20mL of 0.2 M mercury (II) chloride ($HgCl_2$)
- bottle of Coke or Pepsi
- cotton wool
- two 400mL beakers
- 20 mL of 2.0 M hydrochloric acid (HCl)

Figure 1. Equipment needed for this demonstration.

Preparation:

Cut up 5 small (5cm x 5cm) squares of aluminium kitchen foil.

Demonstration Instructions:

1. Lay out a large sheet of aluminium kitchen foil and brush it (wearing gloves) with cotton wool soaked in the mercury (II) chloride solution. Drawing a heart shape or a square is suggested.
2. Show the audience that the original oxide layer is lifted off and a new fluffy oxide layer forms. Heat is also evolved.
3. Transfer to the waste tray without letting dust drop onto bench.
4. Take two small squares of aluminium foil and lay over each beaker so that they form a hollow.
5. Fill one hollow with the hydrochloric acid.
6. Wipe the second foil with mercury (II) chloride and add the acid after a moment or two.
7. The experiment may be repeated using a Coke or Pepsi drink in place of the hydrochloric acid.

Observations:

The impervious aluminium oxide layer will be lifted when mercury (II) chloride solution is added allowing for the aluminium foil to react with hydrochloric acid forming colourless and odourless gas.

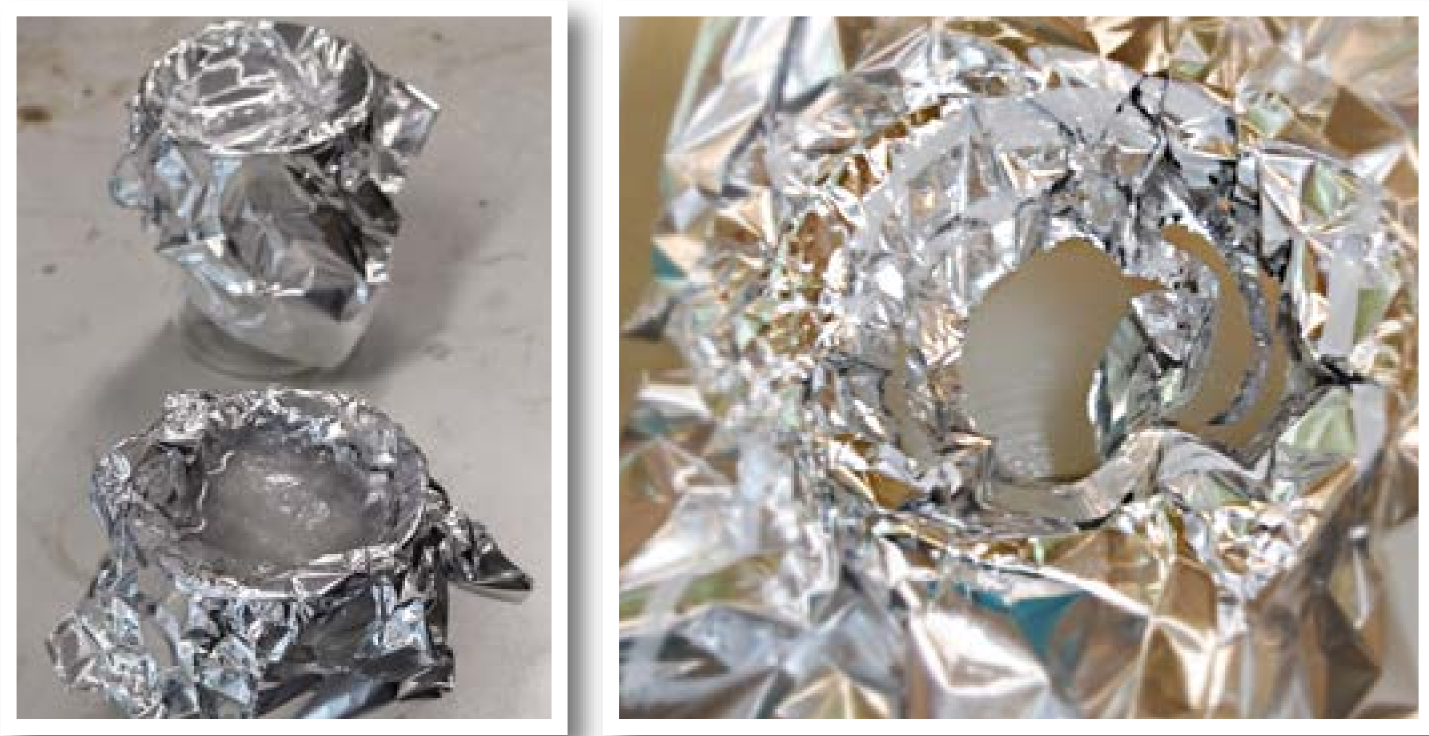


Figure 2. Aluminium foil reacts with hydrochloric acid once the aluminium oxide layer is removed.

Chemical Equation:

$$\underset{\text{(colourless solution)}}{6HCl_{(aq)}} + \underset{\text{(silver solid)}}{2Al_{(s)}} \rightarrow \underset{\text{(white solid)}}{2AlCl_{3\,(aq)}} + \underset{\text{(colourless gas)}}{3H_{2(g)}}$$

or

$$6H^{+}_{(aq)} + 2Al_{(s)} \rightarrow 2Al^{3+}_{(aq)} + 3H_{2(g)}$$

Learning Outcomes:

- Aluminium is coated in a non porous oxide layer which prevents the true reactivity of aluminium being shown in reaction with dilute acid.
- Aluminium's oxide layer can be removed to reveal the true reactivity of the metal.
- Dilute hydrochloric acid cannot readily react with the aluminium oxide but when the oxide layer is removed it can. The gas formed is hydrogen.
- Coke and Pepsi are sufficiently acidic to react with pure aluminium.

Chemical Disposal:

Wrap the waste aluminium and cotton wool in a plastic bag, tie it up and place it into laboratory bin.

DEMONSTRATION 28: Combustion of ethyne

Concepts:

- Incomplete combustion - ethyne foam (acetylene foam)

Safety:

- Acetylene is a flammable gas. If using a small beaker more than half full note that the acetylene foam will over flow and the bubbles may burn on the desk itself
- Do not perform experiment near to bottles of flammable materials
- Safety glasses MUST be worn at all times

Equipment:

- calcium carbide (CaC_2)
- distilled water bottle
- spills matches
- 250 mL beaker
- washing up liquid
- heat proof mat

Figure 1. Equipment needed for this demonstration.

Preparation:

If calcium carbide is in large pieces it will be necessary to break them into smaller pieces using a hammer.

Demonstration Instructions:

- Half fill the beaker with water, add a good squirt of washing up liquid, and add a few small (lentil sized) pieces (4-5) of calcium carbide.
- When sufficient foam has been formed ignite the foam at arms length.

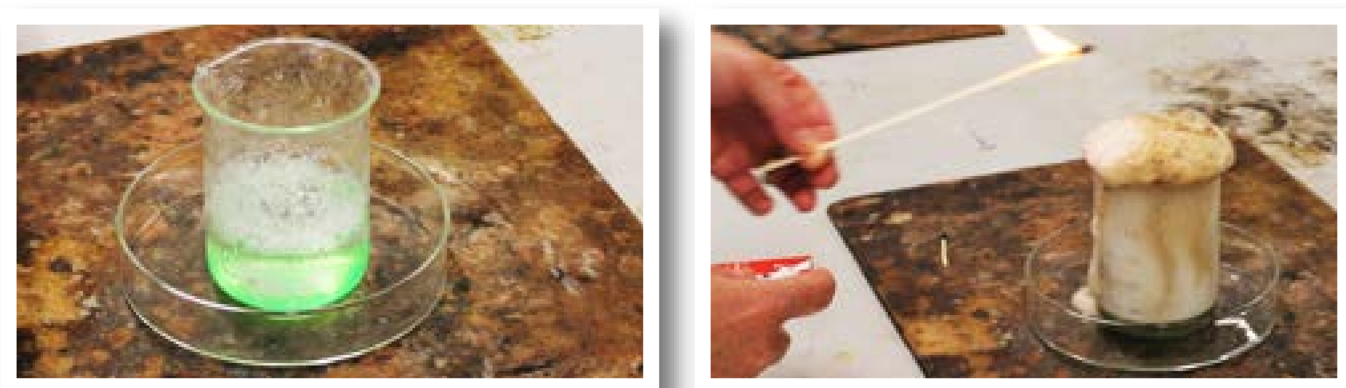


Figure 2. Left – Mix water with washing-up liquid and calcium carbide, right - once the foam has been formed ignite the foam.

Observations:

- The foam ignites. Ethyne, C_2H_2 burns incompletely in air so some blackness seen in flame.
- Occasionally smuts are seen floating in the air.

Figure 3. Foam ignites as ethyne burns incompletely in the air.

Figure 4. After ethyne is used up the flame disappears.

Chemical Equations:

$$CaC_{2(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(aq)} + C_2H_{2(g)}$$

(grey solid) (colourless liquid) (colourless solution) (colourless gas)

and

$$2C_2H_{2(s)} + 5O_{2(g)} \rightarrow 4CO_{2(g)} + 2H_2O$$

(complete combustion)

Learning Outcomes:

- Students should appreciate how flammable is ethyne.
- Students should be able to understand what a non-complete combustion is.

Chemical Disposal:

Dispose of left over solution down laboratory sink and flush with plenty of water.

Additional Information:

Note pure ethyne/acetylene needs an oxygen source to burn completely (as in oxy-acetylene cutters). It can be argued that incomplete combustion is less efficient and uses up more fuel.

DEMONSTRATION 29: Properties of solid carbon dioxide – dry ice

Concepts:

- Sublimation of dry ice (solid carbon dioxide)
- Solubility of carbon dioxide in water

Safety:

- Wear safety glasses at all times
- Use tongs or heating gloves when handling dry ice

Equipment:

- few grams of dry ice (solid carbon dioxide)
- small heat proof mat
- overhead projector
- frying pan
- 1L beaker
- disposable glove or deflated balloon
- universal indicator solution
- 10mL of 0.1 M sodium hydroxide (NaOH)

Figure 1. Equipment needed for this demonstration.

Preparation:

Nil.

Demonstration Instructions:

1. **Overhead Projector Method**
   Put a few lumps of dry ice into a petri dish on an overhead projector.
2. **Balloon or Disposable Glove Method**
   Put a few small lumps into a balloon or into a rubber disposable glove. Knot the end.
3. **Beaker or Frying Pan Method**
   Put a good handful of dry ice into a beaker. Wet a small heat proof mat and stand the filled beaker on it. Wait a few minutes. Alternatively, place some dry ice under a frying pan and listen.
4. **Water Method**
   Fill-up 1L beaker with water and then add 10 mL of 0.1 M NaOH and then universal indicator and stir. Add a few drops of dry ice and observe what happens.

Observations:

1. **Overhead Projector Method**
   Students will be able to see that the solid lump of CO_2 will shrink in size but does not leave a pool of liquid, because CO_2 sublimes at room temperature. Care not to leave it on too long or you may crack the lens! Also be aware that water ice may form below petri dish.
2. **Balloon or Disposable Glove Method (Figure 2)**
   As the dry ice expands the balloon inflates. Passing it around the students can sense there is no liquid in the balloon but a gas is inflating it.
3. **Beaker or Frying Pan Method**
   The beaker will freeze to the mat. When the carbon dioxide sublimes (no liquid seen) the energy to change state must come from somewhere –some comes from the liquid water thus freezing it. Water freezes at 0°C whilst CO_2 sublimes at -78°C. When dry ice is placed under the frying pan it starts to make a loud hissing sound as it sublimes.
4. **Water Method (Figure 3)**
   The solution will change from green to purple as dry ice is added, white fumes are formed and beaker gets very cold.

Figure 2. Placing 3-4 pellets of dry ice into a disposable glove and tying it at the end causes CO_2 gas to expand the glove.

Figure 3. Adding few pellets of dry ice to water with a few drops of universal indicator.

Learning Outcomes:

- Students should be able to understand the different states and their process to go from one to another.
- Students should be able to understand that carbon dioxide sublimes at room temperature and no liquid carbon dioxide can be seen at atmospheric pressure.

Chemical Disposal:

Make sure that any leftover dry ice is “dissolved” in water prior to disposal down the laboratory sink.

DEMONSTRATION 30: Mystery message – phenolphthalein indicator

Concepts:

- pH indicators

Safety:

- Safety glasses and rubber gloves MUST be worn at all times
- Phenolphthalein is a harmful solution and is made up in ethanol, which is flammable. Ensure that hands are washed if contaminated with this solution
- Sodium hydroxide (1.0 M) is harmful, avoid breathing in spray
- Ammonia (1.0 M) is harmful, avoid breathing in spray

Figure 1. Equipment needed for this demonstration.

Equipment:

- A4 paper
- clips
- phenolphthalein indicator
- 1.0 M sodium hydroxide (NaOH) in a spray bottle
- 1.0 M ammonium hydroxide solution (NH_4OH) in spray bottle
- cardboard
- two retort stands

Preparation:

Paint or draw something using solution of phenolphthalein indicator on a piece white paper and allow to dry.

Demonstration Instructions:

- Stick the pre-treated paper on the wall. Spray the dilute alkaline solution (NaOH or NH_4OH).

Observations:

- The alkali will turn the indicator pink and the mystery writing is revealed.

Figure 2. As the white paper, which has been previously drawn on using phenolthalein indicator is sprayed with NaOH the secret message is revealed.

Learning Outcomes:

- Students should be able to understand that phenolthalein indicator turns pink in alkaline solutions and is otherwise colourless.

Chemical Disposal:

Any left over NaOH or NH_4OH can be flushed down the sink with plenty of water.

DEMONSTRATION 31: Disappearing polymer – acetone dissolving polystyrene

Figure 1. Equipment needed for this demonstration.

Concepts:

- Structure of polymers
- Reactivity of polymers

Safety:

- Propanone (acetone) is highly flammable and an irritant
- Safety glasses MUST be worn at all times
- Ensure there are no naked flames nearby as propanone is highly flammable

Equipment:

- 50 mL of propanone (acetone, $(CH_3)_2CO$)
- Supply of paper towels, newspaper or similar
- 1L beaker or some other transparent container
- 5 L beaker
- expanded polystyrene drinking cups or tall thin piece of expanded polystyrene packaging

Preparation:

- Nil.

Demonstration Instructions:

Hold an expanded polystyrene drinking cup over the 1 L beaker and slowly pour about 50 mL of propanone into it. The bottom will fall out of the cup and the propanone will pour straight through into the beaker (Figures 2 and 3).

Observations:

When expanded polystyrene is placed in propanone (acetone), the polystyrene apparently disappears, and the gas bubbles within the material create a fizzing effect as they are released. A small volume of propanone can absorb an impressive volume of expanded polystyrene. The resulting small volume of solid material contrasts sharply with the volume of the original expanded polystyrene.

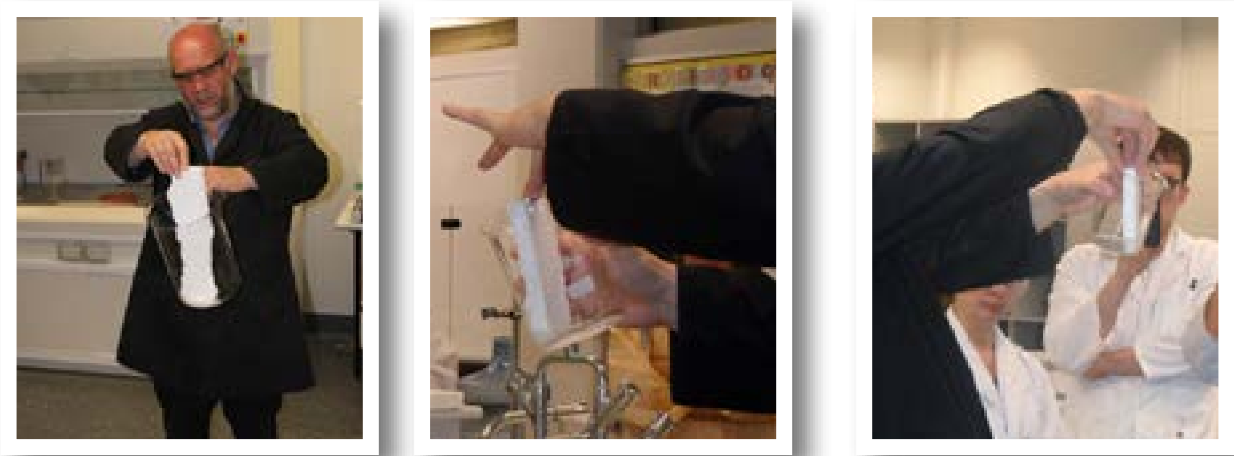


Figure 2. The piece of polystyrene dissolves when placed into acetone.

Figure 3. As polystyrene cup or piece of polystyrene comes into contact with acetone it will dissolve.

Learning Outcomes:

- Students will understand the structure of expanded polystyrene.
- Students will appreciate that the expanded polystyrene does not actually dissolve in the propanone; it merely softens as it absorbs the propanone and allows the gas to escape, thereby collapsing the solid foam.
- Students will appreciate that this is an interesting example of a gas released not by a chemical process, but by a physical process.

Chemical Disposal:

Dispose of the resulting gel from this demonstration by decanting any remaining propanone down the sink and flushing it away with water. The gel can be poured into a throwaway container, such as a screw top coffee jar, and placed in the solid waste bin.

Additional Information:

- Up to 10 L of packing beads will be needed for each demonstration. Other forms of the material will need to be broken into small enough pieces for convenient addition to the 1 L beaker. Provide the supply of material in a large box, from which the demonstrator can easily fill the transparent container with a scoop.
- Expanded polystyrene articles are manufactured from polystyrene granules that incorporate a blowing agent – a substance which, when heated, gives off a gas. This may be a volatile liquid (such as pentane) or a carbonate. These granules are then steam-heated and the gas from the blowing agent expands to produce a foam plastic. This gas is eventually exchanged with air. Thus the gas in the solid foam is largely air.
- The large transparent container is to allow the class to observe the volume of expanded polystyrene pieces being added. A 5 L beaker or a plastic fish tank would be suitable, but note that the latter might be damaged by any propanone accidentally spilt on it. Mark the side of the fish tank at approximately 5 L intervals.
- The supply of paper towels, newspaper or similar is to protect the bench and mop up any spillages. Warning: the polystyrene gel formed is an excellent adhesive, especially where it is not wanted, and can be very difficult to remove from clothes. The resulting gel of polystyrene can be left in a fume cupboard while the propanone evaporates, although this takes some time.
- The Argonne National Laboratory (USA) covers some health and Safety queries about this demonstration: http://www.newton.dep.anl.gov/askasci/chem03/chem03788.htm (website accessed Nov 2015).
- A useful website, well worth a visit, that develops and extends the science behind this demonstration, is: http://www.sciencemuseum.org.uk/educators/classroom_and_homework_resources/resources/shape_shifting_slime.aspx and http://www.practicalchemistry.org/experiments/disappearing-plastic.262.EX.html (websites accessed Nov 2015).

DEMONSTRATION 32: Properties of liquid nitrogen

Concepts:

- Cryogenic liquid
- Liquid to gas conversion
- Physical changes
- Conductors and insulators

Safety:

Safety glasses, lab coat and thermally insulating gloves MUST be worn when handling liquid nitrogen. The vapor of liquid nitrogen can rapidly freeze skin tissue and eye fluid, resulting in cold burns, frostbite, and permanent eye damage even by brief exposure. Liquid nitrogen should be handled in well-ventilated areas. Handle the liquid slowly to minimize boiling and splashing. Use tongs to withdraw objects immersed in a cryogenic liquid - Boiling and splashing always occur when charging or filling a warm container with cryogenic liquid or when inserting objects into these liquids.

Equipment and Chemicals:

- 30 L of liquid nitrogen
- 3 L glass Dewar
- transparent shield
- rubber tubing (approx. 50 cm)
- one banana
- hammer
- 3 raw eggs
- frying pan
- one balloon
- few flowers (carnations are best)

Figure 1 Equipment required for this demonstration.

Preparation:

Make sure that the flowers and eggs are fresh. Blow up balloon. Ensure that there is enough (about 30L) liquid nitrogen for all the activities planned for this demonstration.

Demonstration Instructions:

Rubber Tubing: Place one end of the rubber tubing into liquid nitrogen for about 30 sec and then take it out and while holding the part that was NOT sub-emerged into liquid nitrogen smash it with a hammer.

Banana: Place half of the banana into liquid nitrogen for about 60 sec and then take it out and then hit it with a hammer to show how hard it is.

Balloon: Carefully place blown-up balloon into liquid nitrogen, making sure that your hands don't touch the liquid. After about 30 sec take the balloon out of the liquid nitrogen.

Eggs: Break 3 raw eggs into the frying pan and then pour liquid nitrogen on top of the eggs.

Flowers: Place flowers into the liquid nitrogen for about 30 sec and then take them out.

PLEASE NOTE: Local rules on the use of cryo gloves at appropriate times may be advised. Mr Tim Harrison is a very experience liquid nitrogen user and knows when and where insulated gloves should be used.

Observations:

Rubber Tubing (Figure 1): The part of tubing that is placed in liquid nitrogen will freeze and when hit with a hammer it shatter into small pieces. The audience's attention should also be drawn to rubber as a heat insulator so only the end dipped into liquid nitrogen is made colder. Ensure that the end of the tube that is not being dipped into liquid nitrogen is held away from the audience as it will deliver a shower of liquid nitrogen droplets.

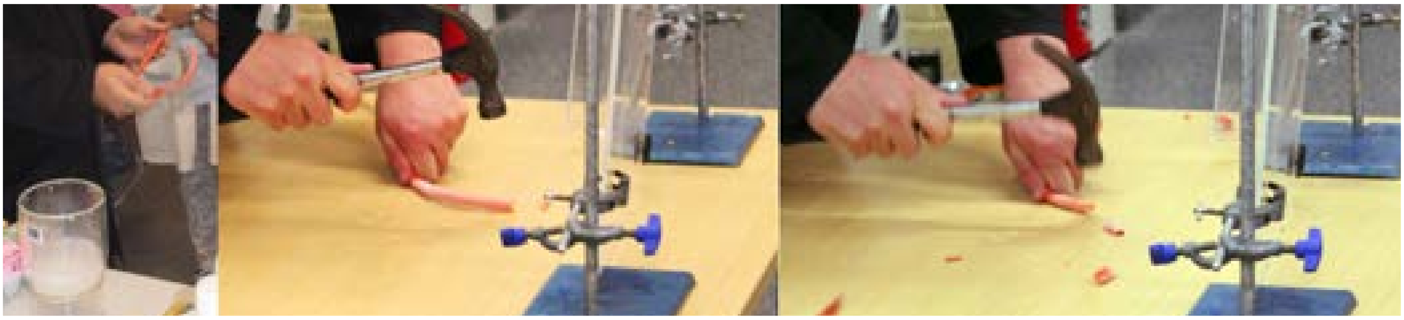


Figure 1. Hitting frozen part of the rubber tubing with hammer.

Banana (Figure 2): After the banana has been placed in liquid nitrogen it hardens to the point that when you hit it with a hammer it will shatter into small pieces. Makes sure there is a shield between the audience so that the sharp pieces of the banana don't hit anyone or are not scattered on the floor where an audience member may be able to to touch them.

Figure 2. Hitting the frozen part of the banana with a hammer.

Balloon (Figure 3): The air molecules inside the balloon will slow down due to the extreme cold temperature of the liquid nitrogen and thus the pressure will be reduced and the balloon will shrink. After the balloon is taken out of the liquid nitrogen the temperature starts to increase and air molecules move faster and thus the pressure increases and balloon expands again.

Figure 3. Placing balloon into liquid nitrogen.

Eggs (Figure 4): After the liquid nitrogen is poured on top of the raw eggs, it appears that the eggs are cooking, but they are not, they are simply being frozen. After a few minutes as the eggs defrost they go back to their original raw form.

Figure 4. Break raw egg into a frying pan filled with liquid nitrogen.

Flowers (Figure 5): Place a flower head into liquid nitrogen for 20 sec or so. After the flowers are removed from liquid nitrogen, the soft petals are frozen and when you place them in your hand they shatter into tiny pieces and make a scratchy noise. The best flowers to use are those whose petals have a large surface area and are open, such as chrysanthemums.

Figure 5. Flowers placed into liquid nitrogen.

Learning Outcomes:

- Students will understand what a cyrogenic liquid is.
- Students will be able to recognise the difference between physical change and chemical change.
- Students will appreciate the changes to objects when subjected to extreme cold.
- Students will be able to recognise that a rubber is an effective insulator.

Disposal of Chemicals:

Dispose of raw eggs into appropriate bin and allow the rest of the unused liquid nitrogen to convert into a gas.

DEMONSTRATION 33: Iodine clock reaction

Concepts:

- Rates of reaction
- Redox reactions
- Test for iodine

Safety:

Safety glasses MUST be worn at all times. Solution A is harmful. Solution B is corrosive. The iodine formed is hazardous. Add a few crystals of sodium thiosulfate prior to disposal.

Equipment and Chemicals:

- solution A: Mix 0.5 g soluble starch, 7.5 ml ethanoic acid (glacial acetic acid), 1.05 g sodium ethanoate (acetate), 12.5 g potassium iodide and 2.45 g sodium thiosulfate and make up to 1 litre with water
- solution B: Take 50 ml (30-35%, also described as '100 Vol') of hydrogen peroxide and make up to 1 litre with water
- 4 x 400 mL beakers
- 2 x 250 mL measuring cylinders
- distilled water bottle
- white background

Figure 1. Equipment and chemicals required for this demonstration.

Preparation:

Mark 2 x 400 mL beakers with a letter 'A'. Add 200 mL of Solution A. Stand on white background. Mark 2 x 400 mL beakers with a letter 'B'. Add 150 mL of Solution B to on beaker and 100 mL of Solution B to the other. Measure out 50 L of water. Note the dissolving of the soluble starch has its own challenges due to starch source. Some starches need to dissolve in hot water and then cooled. The mass of starch used must turn the eventual solution black and not just brown.

Demonstration Instructions:

Show students that you are diluting the latter beaker's contents with 50 mL of water. Using both hands add each Solution B to Solution A and swirl equally to mix. Replace the beakers onto the white background and wait.

Observations:

Depending on the temperature the reaction of the more concentrated reactants will turn blue-black after 30-35 seconds (Figures 2 and 3). The less concentrated mixture will change a round 30 seconds later.

Figure 2. Colourless solution suddenly turns dark blue colour in around 30sec.

Figure 3. Demonstrate to the audience how the solution suddenly changes colour.

Learning Outcomes:

- Students will understand redox reactions as a transfer of electrons.
- Students should be able to understand that concentration of reactants is one factor that affects rates of reactions.
- Students will understand that starch is used as a test for the presence of iodine.

Chemical Equations:

The basic reaction is: $H_2O_{2(aq)} + 2I^-_{(aq)} + 2H^+_{(aq)} \rightarrow I_{2(aq)} + 2H_2O_{(l)}$

(This reaction is the rate determining step and is first order with respect to both H_2O_2 and I^-)

As soon as the iodine is formed, it reacts with the thiosulfate to form tetrathionate ions and recycles the iodide ions by the fast reaction: $2S_2O_3^{2-}{}_{(aq)} + I_{2(aq)} \rightarrow S_4O_6^{2-}{}_{(aq)} + 2I^-_{(aq)}$

As soon as all the thiosulfate is used up, free iodine (or, strictly, I^{3-} ions) remains in solution and reacts with the starch to form the familiar blue-black complex. The time for the blue colour to appear can be adjusted by varying the amount of thiosulfate in solution A so a 'clock' of any desired time interval can be produced.

Disposal of Chemicals:

Addition of a solution of sodium thiosulfate to the iodine will decolourise the solution and reduce the iodine back to iodide for disposal.

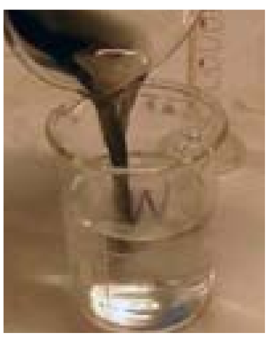


Figure 4. To dispose of iodine, add sodium thiosulfate to iodine to convert iodine to colourless iodide.

DEMONSTRATION 34: Blue bottle

Concepts:

- Redox reactions
- Reversible chemical reactions

Safety:

Safety glasses MUST be worn at all times. Sodium hydroxide solution is corrosive and methylene blue solution is an irritant dissolved in a flammable solvent. Keep away from open flame.

Equipment and Chemicals:

- 1 litre conical flask with bung to stopper or 1 litre Schott bottle with screw cap
- large (500 mL or 1 litre) measuring cylinder
- 10 ml measuring cylinder
- 600 mL of 0.5 mol L^{-1} sodium hydroxide or potassium hydroxide solution
- 5 mL of 0.1 % methylene blue solution (0.05g in 6.0 g of ethanol)
- 20 g of glucose

Figure 1. Equipment required for this demonstration.

Preparation:

Dissolve all components in each other at least 10 mins beforehand if you wish to start with a colourless solution. If left longer the mixture will become a urine colour.

Measure out 600 mL of 0.5 mol L^{-1} sodium hydroxide or potassium hydroxide solution and place into a large conical flask or Schott bottle. Add 5 mL of 0.1 % methylene blue solution (0.05g in 6.0 g of ethanol into a 1 L conical flask). Add 20 g of glucose and shake until dissolved. At this stage the solution will be blue and will take a while to become colourless. Naturally the time taken for this change will be temperature dependant.

Demonstration Instructions:

If the mixture is previously prepared and has had time to become colourless then all that needs to be done is to shake the stoppered container for 10 seconds.

Observations:

A freshly made mixture will turn from colourless to blue on shaking and will revert to colourless on standing after a few minutes. If the mixture was made up more than 10 minutes ahead of schedule then it will start urine colour so the demonstrator can tease the audience that it is their own urine!

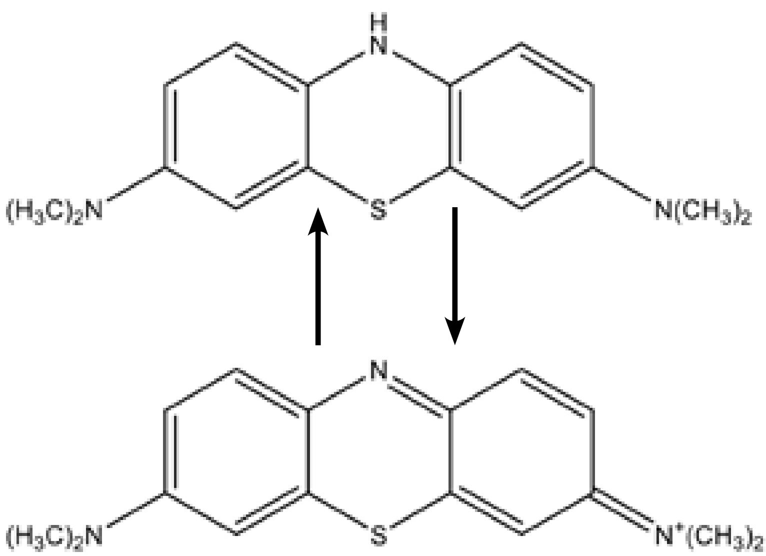
Figure 2. The colourless solution will turn blue upon shaking.

Learning Outcomes:

- Students will understand redox reactions as a transfer of electrons.
- Students will be able to recognise reversible reactions.

Chemical Equation:

Colourless, reduced form



Blue, oxidised form Cl^-

Methylene blue was isolated in 1891 by Paul Ehrlich who later became a Nobel Prize winner for medicine in 1908 for his work on autoimmunity.

Disposal of Chemicals:

Dispose of all chemicals down the sink and wash down with plenty of water.

DEMONSTRATION 35: Hot ice

Concepts:

- Exothermic reaction
- Ionic bonds

Safety:

- Safety glasses MUST be worn at all times.
- Sodium acetate (ethanoate) trihydrate is a mild irritant. Gloves should be worn.
- Heat resistant gloves are recommended to handle hot beaker.

Figure 1. Equipment required for the Hot Ice demonstration.

Equipment and Chemicals:

- A 250mL beaker and a watch glass
- 25g of acetate (ethanoate) trihydrate and a teaspoonful of water (~4-5 ml)
- A hot plate to warm up the solution
- A ceramic tile
- Hand warmers (optional)

Preparation:

In a small beaker or pan, add 25g of sodium ethanoate trihydrate and a teaspoonful of water (~4-5ml). Warm the container until the crystals dissolve and form a clear liquid. There is no need to boil the solution. Cover the container to prevent dust entering and starting the crystallisation. Allow the solution to cool to room temperature. Should crystals form in the container, gently heat these until they dissolve again (alternatively, filter the solution, but this often results in crystallisation occurring). Place one small crystal of sodium acetate on a tile or other smooth surface. Slowly pour the cooled supersaturated solution onto the crystal.

Figure 2. Carefully and slowly pour the saturated sodium acetate solution onto a tile and watch the sodium acetate crystallise in front of your eyes.

Demonstration Instructions:

It is recommended that the solution is prepared prior to the demonstration and tested to make sure it works. Dust particles and too much movement can cause premature crystallisation. Make-up several beakers from a stock solution and pour into warm beakers and leave to cool. That way you should have at least one solution to use in the demonstration.

Observations:

- The crystals will dissolve as the solution is being warmed up.
- If the solution is cooled down not too quickly crystals will not form again. If crystals appear, rewarm the solution.
- If poured slowly, you can create "mountains" of white crystals.

Figure 3. Example of a 'mountain' of Hot Ice.

Learning Outcomes:

- Students should be able to distinguish between exothermic and endothermic reactions
- Students should be able to understand that freezing is an exothermic process
- Students should be able to identify that bonding in crystals is ionic

Chemical Equation:

- $CH_3COONa.\ 3H_2O_{(s)} \rightarrow CH_3COO^-_{(aq)} + Na^+_{(aq)}$
- $CH_3COO^-_{(aq)} + Na^+_{(aq)} \rightarrow CH_3COONa.\ 3H_2O_{(s)}$

Disposal of Chemicals:

- Ensure product is covered with moist soil to prevent dust generation and dispose of to approved council landfill. Contact the manufacturer/supplier for additional information (if required).

DEMONSTRATION 36: Alginate worms

Concepts:

- Polymers
- Cross linking

Safety:

- Safety glasses MUST be worn at all times.
- Sodium alginate is a mild irritant with occasional skin sensitization.
- The beaker could be hot. Heat resistant gloves are recommended.
- Calcium chloride is harmful when swallowed and causes serious eye irritation.

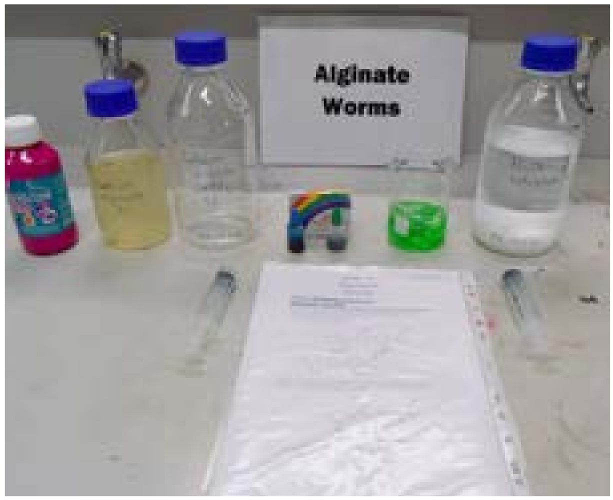


Figure 1. Equipment needed for this demonstration.

Equipment and Chemicals:

- Approx 5mL of 2% sodium alginate suspension or Gaviscon®
- Dropping pipette or needleless syringe
- 2 x 150mL beakers
- Approx 100mL 1% sodium chloride solution
- Approx 100mL saturated calcium chloride solution

Preparation:

- Add the calcium chloride solution into one of the beakers and the sodium chloride solution into the other.
- Using the pipette, squirt the sodium alginate/Gaviscon® solution into the calcium chloride solution. A couple of drops of food dye can be added to the sodium alginate/Gaviscon® solution to see the crosslinking process better. 'Worms' can be made by dispensing the sodium alginate/Gaviscon® solution at a fast rate. Beads can also be made by dispensing at a slower rate.
- Remove a few of your worms straight away and put them into the beaker of sodium chloride solution.
- Swirl both beakers gently and observe what happens to the worms in each one. You can remove and squeeze the worms as well as observing their appearance. You will need to wait a few minutes for all the reactions to be complete.

Figure 2. Formation of alginate worms using different food colourings.

Demonstration Instructions:

- Alginate is a common food additive, E400. It is used as a thickener, stabiliser and gelling agent. It is often found in ice cream, where it is used to thicken the product so that even if it melts, it does not drip too much.
- Solution can be made ahead of time and reused if big amounts are made.

Observations:

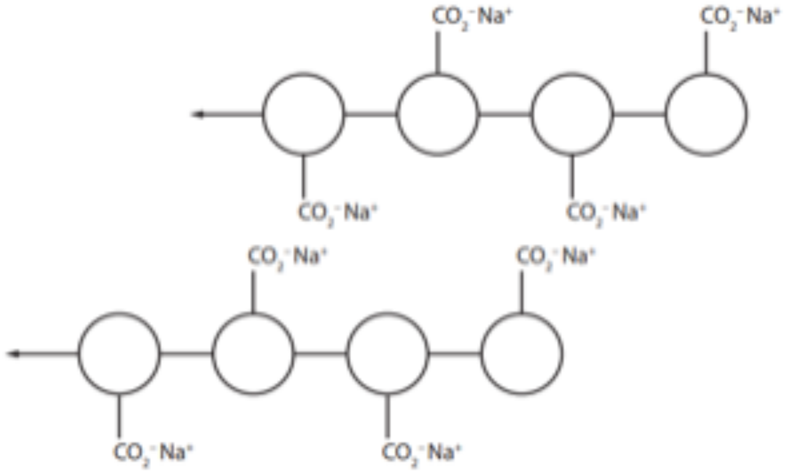
- As the coloured sodium alginate/GavisconR solution is added to the calcium chloride solution crosslinking can be found evident. By removing the "worms" from the calcium chloride solution to the sodium chloride solution crosslinking is no longer apparent and beads can be seen in solution. The former is quick and the latter takes a while.

Learning Outcomes:

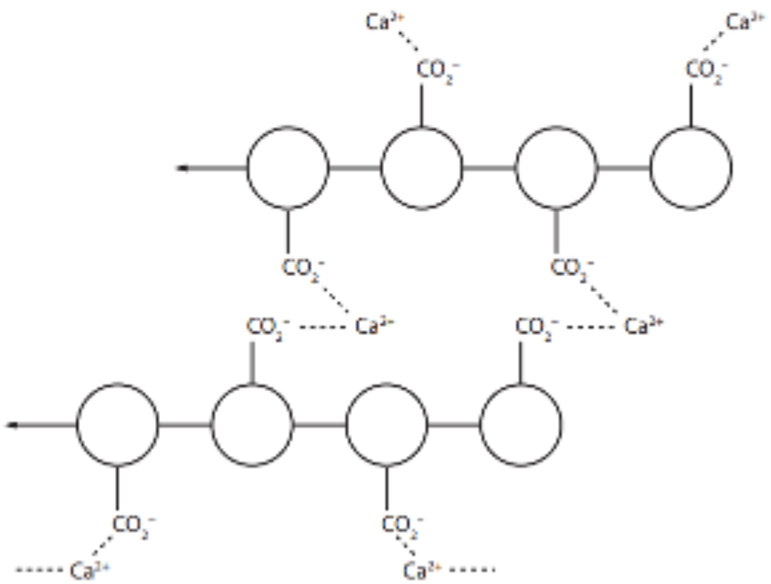
- Students should be able to explain polymers
- Students should be able to identify different types of polymers
- Students should be able to explain what is a cross-linked polymer and its properties

Chemical Equation:

- Alginate polymer in NaCl solution



- Alginate polymer in $CaCl_2$ solution



Disposal of Chemicals:

- Solutions can be kept to reuse later.
- During disposal, ensure product is covered with moist soil to prevent dust generation and dispose of to approved Council landfill. Contact the manufacturer/supplier for additional information (if required).

DEMONSTRATION 37: Thermochromic paints

Concepts:

- Leuco dyes
- Liquid crystals
- Refraction index

Safety:

- Be careful when pouring hot water into polystyrene cup.
- Make sure students wear lab coats and safety glasses in case of a hot water spill

Equipment and Chemicals:

- Paint brushes
- Polystyrene cup
- Kettle
- Thermometers
- Thermochromic paints of different colours
- Hairdryer

Figure 1. Equipment required for this demonstration.

Preparation:

- Get kettle ready to use and have a polystyrene cup with thermochromic paint on it already.

Demonstration Instructions:

- Demonstrate painting one colours onto the bottom half of a polystyrene cup.
- Students observe what happens when the paint is dried with a hairdryer – colour will disappear.
- Add some cold water and the colours should reappear.
- Add some hot water from the kettle (not boiling water) and the colour disappears.

Observations:

- Thermochromic paints become colourless in warm temperatures.

Figure 2. The paint on the cups will disappear when you pour hot water into the cup and as the hot water cools down the paint will re-appear.

Learning Outcomes:

- Students should be able to understand the difference between physical and chemical changes
- Students should be able to understand diffraction of light by diffraction gratings and constructive and destructive interference
- Students should be able to explain behaviour of liquid crystals and leuco dyes

Chemical Equation:

- NIL

Disposal of Chemicals:

- Polystyrene cups can be disposed of in the general rubbish bin.

DEMONSTRATION 38: Methane mamba and methane bubbles

Concepts:

- Combustion
- Volatile substances
- Density

Safety:

- Detergent and glycerol solution
- Top half of a 1L transparent plastic bottle
- Delivery tube with stopper which fits into the plastic bottle's neck
- Clamp and retort stamp to hold soda bottle
- 1L Schott bottle
- 1m ruler with splint attached at one end
- Lighter
- Source of natural gas

Equipment and Chemicals:

- Detergent and glycerol solution
- Top half of a soda bottle
- Delivery tube with stopper which fits into the soda bottle's neck
- Clamp and retort stamp to hold soda bottle
- 1L Schott bottle
- 1m ruler with splint attached at one end
- Lighter
- Source of natural gas

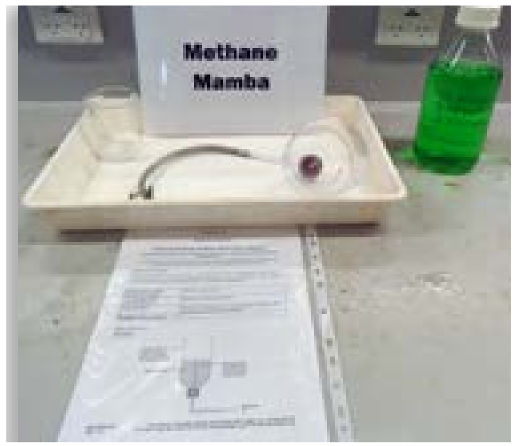


Figure 1. Equipment required for this demonstration.

Preparation:

- Methane gas is bubbled into soap solution. As the bubbles rise, they are ignited with a lighted splint.
- Using the retort stand the clamp, secure the soda bottle in a vertical position with the stoppered end down
- Attach the delivery tube to both the soda bottle's neck and the methane source. Fill the soda bottle with the detergent/glycerol solution.
- Turn the gas on.
- The rate of gas flow can be adjusted so that bubbles are formed slowly or fast.
- If bubbles are stable above the bottle, about 10 cm high, the bubbles can be removed by hand and allowed to float in the air.
- You may wish to put a trap between the methane/natural gas source and the soda bottle apparatus to avoid suck back getting detergent into gas taps.

Figure 2. Set-up half a plastic 1L bottle half filled with detergent and glycerol solution and connect natural gas to the bottle and slowly start bubbling gas through the solution.

Demonstration Instructions:

The bubbles produced first will be filled with air and will therefore sink. Discard these bubbles as they will burn too hot. Bubbles formed later will rise. If easier, an assistant can light the splint and apply the flame to the floating bubbles.

Observations:

- As gas is pushed through the detergent and glycerol solution bubbles are formed.
- Once lit, bubbles turn into flames.

Figure 3. Avoiding initial foam (which will also contain air burn too hot), scoop up bubbles from the top of the plastic bottle that are generated as the gas is bubbled through the bottle, extend your arm straight (palm up and fingers down). Ensure you keep your fingers together and palm flat and do not drop your arm. Burst any bubbles on the underside of your hand and get someone else to light the gas bubbles.

Learning Outcomes:

- Students will understand gas density and how methane is lighter than air
- Students will understand that methane is flammable

Chemical Equation:

$$CH_{4\,(g)} + 2O_{2\,(g)} \rightarrow CO_{2\,(g)} + 2H_2O_{(l)}$$

Disposal of Chemicals:

- Any left over detergent pour down the drain with plenty of water.

DEMONSTRATION 39: Water beads

Concepts:

- Superabsorbent Polymers
- Refraction index

Safety:

- Make sure that all water beads are separated from the water once the demonstration is finished.

Equipment and Chemicals:

- Large glass container with flat bottom
- Picture or images
- Enough water beads to cover base of container
- Enough water to cover all the water beads
- Sieve to retrieve water beads

Figure 1. Equipment needed for the water bead demonstration.

Preparation:

- Place pictures/images under Pyrex container. Cover base of Pyrex container with water beads.
- If water beads are being used for the first time allow at least 2hrs for them to 'grow' (absorb water) from the 'starter' seeds.

Demonstration Instructions:

- Before adding water to Pyrex container ask audience if they can see the pictures/images. Add enough water to cover water beads and ask question again.
- To start experiment again, drain water from Pyrex container using a sieve to not lose any water beads.

Observations:

- As the water is added to the water beads, their refraction index changes and allows us so see the images or pictures underneath.

Figure 2. First image shows blurry image under the water beads. As water is being added the images are becoming more clearer. The last image is clearly visible as all the water beads are submerged in water.

Learning Outcomes:

- Students should be able to understand polymers
- Students should be able to link properties of polymers to the structure of polymer
- Students should be able to draw structure of polyacrylamide
- Students should be able to understand refraction index in relation to some polymers

Chemical Equation:

- NIL

Disposal of Chemicals:

- Water beads can be reused, but need to be kept in water.
- Do not allow water beads (or their seeds) to be flushed down the sink where they can cause blockages.

Bristol ChemLabS (University of Bristol, UK) have recently made a series of short videos of 'how to do' some of these chemistry demonstrations. Where they match, we have listed them below. You can go to the Teacher Demonstration Channel at: https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN

Demonstration Number	Link
1	Reactions of lead nitrate and potassium iodide are done in solutions: https://www.youtube.com/watch?v=mwZrhwAJ1PU&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=23 This link is to a channel created for younger students: https://www.youtube.com/watch?v=J2QYE20bWQ8&list=PLIRvUUtODph8snb4RIWxAePYk30ISQGb1
3	This video also shows Mg burning within dry ice: https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
4	This video also includes potassium and lithium reactivity with water: https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN https://www.youtube.com/watch?v=RI-ji7aq3U&list=PLRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=74
5	This video shows comparison of hydrogen and helium balloons burning: https://www.youtube.com/watch?v=3wVne3fJUmg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=12
6	This video is limited to condensation of oxygen from the air using liquid nitrogen and combustion of a few elements in oxygen: https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
7	This reaction requires a dark room: https://www.youtube.com/watch?v=6FEDfLA05AQ&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=29 https://www.youtube.com/watch?v=Lvot13wuOFA&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=48
9	See also "Elephant's Toothpaste' demonstration: https://www.youtube.com/watch?v=V3E4LcBRtLE&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=52
10	https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
12	https://www.youtube.com/watch?v=OwDCviT7IGA&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=47&t=2s Above reaction is a variant of the B-Z reaction https://www.youtube.com/watch?v=bZaGvzzOgmg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=20
14	https://www.youtube.com/watch?v=XNy8_uSUm5Y&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=7
15	https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN

20	Uses glucose as the reducing agent: https://www.youtube.com/watch?v=wNWM3o6pHzI&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=58
22	https://www.youtube.com/watch?v=9ONjAiltW-0&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=8
23	https://www.youtube.com/watch?v=-be_GSaxVr8&ab_channel=BristolChemLabS This video is linked to flame tests: https://www.youtube.com/watch?v=OEf2Nm-rn9Q&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=18
25	https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
26	Please note that this demonstration, only works with cloth or paper money: https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
27	https://www.youtube.com/watch?v=xZSciUqbgnc&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=55
28	Includes the acetylene cannon: https://www.youtube.com/watch?v=h81sQ5mWHhc&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=19
29	This video show compilation of other possible dry ice experiments: https://www.youtube.com/watch?v=LGkooMo_4o4&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=6
30	https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
31	https://www.youtube.com/watch?v=IwiWtuNsMgY&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=16
32	https://www.youtube.com/watch?v=CiS8Bk10BWM&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=22 There are individual liquid nitrogen demos: https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
33	https://www.youtube.com/watch?v=ffQQkhuXDdA&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=13 See also 'Old Nassau Clock Reaction': https://www.youtube.com/watch?v=DjJk7ZEKuAg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=54
34	A pink bottle variant is also available: https://www.youtube.com/watch?v=GwD81pysEw8&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=10
35	https://www.youtube.com/watch?v=zOabdczginY&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=11
36	https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN
38	https://www.youtube.com/watch?v=Zs56-Tclii8&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=2
39	https://www.youtube.com/watch?v=Onvi5wjcdXg&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN https://www.youtube.com/watch?v=rmvC3nXY_pQ&list=PLIRvUUtODph9qC4rVinCdEIYcKWZ9tUQN&index=69

Sources of demonstrations

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6. Dr Trent Dickeson, University of Newcastle, NSW, Australia
7. Mr Tim Harrison, School of Chemistry, University of Bristol, UK
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