All quantities are per pupil or per group of pupils working together


eye protection must be worn


IRRITANT propanone


HIGHLY FLAMMABLE propanone

1: Alien Blood and Messy Volcanoes

● Basic level ● 30 minutes total

Requirements

ALIEN BLOOD
spatulas
10 cm^3 measuring cylinder
dropping pipette
pestle and mortar to grind up chalk
stirring rod

eye protection
disposable gloves for clearing up afterwards

orange chalk (ground up) or curry powder
liquid detergent
expanded polystyrene tiles or packaging chips
propanone
'liver salts' mixture; equal amounts of sodium hydrogencarbonate, $NaHCO_3$, citric acid and magnesium sulphate, $MgSO_4$

MESSY VOLCANO
sodium hydrogencarbonate, $NaHCO_3$
flour or polystyrene for packing
newspaper

red food colour
ethanoic acid, (0.1mol dm^{-3}), or colourless vinegar

Method

See pupils' sheet.

Safety advice

Ensure good ventilation so that propanone fumes do not build up.

Chemical background

ALIEN BLOOD
The propanone dissolves the polystyrene. In the presence of water, the 'liver salts' mixture then reacts to produce carbon dioxide gas which fizzes. The dyes are added to look like Alien blood.

MESSY VOLCANO
The ethanoic acid reacts with the sodium carbonate to produce carbon dioxide. This is messy, so use newspaper to cover working surface.


eye protection must be worn


IRRITANT sodium hydroxide solution


HARMFUL barium chloride solution


HIGHLY FLAMMABLE phenolph-thalein solution

2: Chemical Magic

● Basic level ● 30 minutes total

Method

See pupils' sheet.

Water into wine
Requirements

wine glasses (2)
milk bottle
wine carafe (or similar)

eye protection

sulphuric acid, H_2SO_4 (0.1 mol dm^{-3})
barium chloride, $BaCl_2$ (0.1 mol dm^{-3})
sodium hydroxide, NaOH (0.1 mol dm^{-3})
phenolphthalein indicator solution

Safety advice


eye protection must be worn


HARMFUL barium chloride
sodium hydrogen-sulphite
potassium thiocyanate
solid


do not drink

Pupils should be warned not to drink any of the solutions they make.

Wash the carafe and milk bottle carefully after use.

Chemical background

Phenolphthalein is a narrow range indicator. It is purple coloured within the pH range 9-14. At other pH it is colourless. A faint white precipitate forms at pH 1-2.

Barium chloride reacts with sulphate ions to form a white precipitate, barium sulphate:

$BaCl_2(aq) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + 2HCl(aq)$

Mysterious jug Requirements

weighing balance
500 cm^3 measuring cylinder
500 cm^3 beaker
stirring rod
spatula
1 jug and 6 glasses

eye protection

iron(III) ammonium sulphate, $FeAl(SO_4)_2$
potassium thiocyanate, KSCN
barium chloride, $BaCl_2$
potassium hexacyanoferrate(II), $K_4[Fe(CN)_6]$
tannic acid (gallotannic acid)
tartaric acid, 2,3-dihydroxybutanedioic acid
sodium hydrogensulphite, $NaHSO_3$

Safety advice

Pupils should be warned not to handle any of the solids or drink any of the solutions they make.

Sodium hydrogensulphite liberates toxic sulphur dioxide with acid and thiocyanates liberate toxic gases with concentrated acids.

Chemical background

The iron(III) aluminium sulphate reacts with the other dilute solutions in the following ways:

Glass A: The thiocyanate ion forms a deep red complex with iron(III).
Glass B: Barium ions form a white cloudy precipitate with sulphate ions.
Glass C: The hexacyanoferrate ion forms a deep blue complex with iron(III), Prussian Blue.
Glass D: Tannic acid forms a greenish complex with iron(III).
Glass E: Tartaric acid forms a greenish complex with iron(III).
Glass F: Hydrodgensulphite ion forms an amber product with iron(III).

3: Crunchy Foam and Microwave Meringues

● Basic level ● 30 minutes total


hot sugar can cause bad burns


the product must not be eaten if made in the laboratory

Introduction and chemical background

When sugar solution is heated to high temperature, it begins to break down into glucose and fructose. This breakdown is speeded up by the addition of an acid. The result is a syrup containing a mixture of three sugar solutes - glucose, fructose and sucrose. Crystals will not easily form in such a mixture.

Syrup or honey contain weak acids. These acids react with hydrogencarbonate to release CO_2 gas. The trapped gas forms a solid foam in the sugar/syrup mixture and makes a sweet honeycomb.

This is a solid foam - gas is dispersed in a sugar matrix.

Requirements

large saucepan
greased dish
2 tablespoons
a teaspoon
spoon or similar for stirring
tripod, gauze mat, heat proof mat
insulated glove (or similar) for carrying hot pans
4 tablespoons of sugar
2 tablespoons of golden syrup or honey
heaped teaspoon of sodium hydrogencarbonate, $NaHCO_3$

Method

See pupils' sheet.

Microwaves have different power ratings – you may need to adjust the timings to suit your appliance. To avoid overcooking the meringues, first cook on high power for 30 seconds. If the meringues are puffed up and white they are ready. If they look a little flat, cook for another 10 seconds.

Safety advice

Ensure that your pupils are aware of the danger of burns from hot sugar and protect themselves and the lab bench using insulated gloves (or similar) and heat proof mats.
Warn your pupils not to eat the foam if made in the laboratory.
This experiment could be done at home using edible quality sodium hydrogencarbonate.
Make sure that you have parent's/guardian's consent (for suggested permission form see page 13).


eye protection must be worn.


HARMFUL
iron sulphate
copper sulphate


wear gloves for handling crystals

4: Crystal Growing

● Basic level ● 30 minutes to prepare
● Several days to crystallise

Requirements

sodium chloride, NaCl
copper sulphate, $CuSO_4.5H_2O$
sodium sulphate, Na_2SO_4
potassium chromium sulphate, $KCr(SO_4)_2$
iron(II) sulphate, $FeSO_4.7H_2O$
ammonium sulphate, $(NH_4)_2SO_4$
potassium aluminium sulphate, (alum), $KAl(SO_4)_2$
potassium hexacyanoferrate(III), $K_3[Fe(CN)_6]$

eye protection
disposable gloves
weighing balance
filter funnels
filter paper
250cm^3 beakers
evaporating basins
cotton thread
electrical wire (small gauge)
object to coat in crystals (e.g. a cross)
stirring rods
forceps

Method

See pupils' sheet.

Safety advice

Pupils should avoid handling the crystals, use forceps or wear gloves, and wash their hands after handling these solutions.

5: Foam Fire Extinguisher

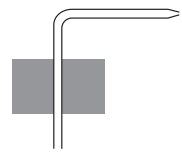
● Basic level ● 30 minutes total

Requirements

2 x 50 cm^3 beakers
50 cm^3 measuring cylinder
100 cm^3 conical flask
bung with delivery tube drawn out into a fine nozzle
(this will make it easier to control the jet)
spatulas
stirring rods
dropping pipette

aluminium sulphate powder, $Al_2(SO_4)_3$
sodium hydrogencarbonate, $NaHCO_3$
washing up liquid or liquid detergent

eye protection
protective clothing (e.g. lab coats)



Method

See pupils' sheet.

Safety advice

Avoid foam in the eye.

The foam will make the floor slippery; ensure that pupils direct their foam jets at a sink.

Chemical background

The sodium hydrogencarbonate releases carbon dioxide when it reacts with the acidic aluminium sulphate solution. The detergent is a foaming agent.

The carbon dioxide acts as a blanket which excludes air from the fire. The foam traps the carbon dioxide and slows down the rate at which it diffuses away.

6: Floating Soap Bubbles

● Basic level ● 30 minutes

Requirements

a wand for blowing soap bubbles (you can make one from wire)
a large transparent container with an open top (an empty 45 dm^3 aquarium works well)
shallow glass dish to fit inside the large container (glass baking dish)
straws and string for the large wand

soap solution: 10% liquid detergent
85% distilled or deionised water
5% glycerine
stir the mixture, do not shake.

20 g sodium hydrogencarbonate, $NaHCO_3$
250 cm^3 colourless vinegar or 0.1 mol dm^{-3} ethanoic acid

• Butterfingers (0117 986 6690) supply bubble making accessories.

Method

See pupils' sheet.

Safety advice

Wear eye protection when blowing large bubbles.
The floor may be become slippery.

Chemical background

A soap molecule has a long tail which is water-insoluble (hydrophobic) and a small electrically charged head which is water soluble (hydrophilic). When soap molecules are added to water, they tend to migrate to the surface and orient themselves so that their water soluble end points towards the water and the long tail sticks out of the water. When a wand is placed in the solution and then withdrawn, the water tends to drain from the inside of the film, making the surface begin to collapse on itself forming a multilayered spherical film.

A soap bubble is round since the surface of the soap film which forms tends to contract to take up the smallest possible surface area. In the walls of the bubble, the water drains to the bottom of the bubbles producing a small bump on the bottom. When the top of the bubble becomes too thin to support the total mass of the bubble, it breaks.

The colour of the bubbles is due to the interference of the light being reflected from the inner and outer surfaces of the film. The film is of varying thickness and so different areas of the bubbles will have different colours.

The floating bubbles become larger as carbon dioxide moves through the soap film.
The bubble becomes heavier and sinks lower into the CO_2 in which it is floating.


wear gloves to avoid staining hands


avoid skin or eye contact

7: pH Painting at Home

● Basic level ● 30 minutes

Requirements

TO MAKE THE PURPLE pH PAPER:
1 small red cabbage
white blotting paper
cheese grater and bowl
sieve
a large bowl
eye dropper (or similar) if available
access to a warm oven or hair dryer (optional)

TO MAKE THE pH 'PAINTS':
concentrated lemon juice
baking soda
washing powder
some water-tight containers
paint brushes
protective clothing and household gloves to prevent staining of gloves and hands
eye protection if available

Method

See pupils' sheet.

Safety advice

The work must be carried out under adult supervision, after written permission has been obtained (see page 13).
Wear rubber household gloves.
Work on a stainless sink surface near a tap.
Although the chemicals involved are household items, if you do spill anything on your skin, wash it off with water and thoroughly rinse your eyes should you splash anything in them.

Chemical background

The purple colour of the red cabbage is due to a mixture of natural dyes present. Under different conditions of pH, the dyes have different structures and therefore absorb different wavelengths of light.

You will find that the paints often dry to a different colour.
This is because pH is a measure of the **concentration** of acid or alkali. As the 'paint' dries the water evaporates, and the concentration of the acid or alkali effectively increases.
This means that a 'paint' which is blue when wet may dry to a green colour.
Similarly, a 'paint' which is green when wet may dry to a yellow.

8: Rainbow Reaction Neutralisation demonstration


eye protection must be worn


HARMFUL sodium hydroxide

● Basic level ● less than 30 minutes

Requirements

50 cm^3 burette with bung
syringes to dispense up to 20 cm^3

eye protection

sodium hydroxide, NaOH, (0.1 mol dm^{-3})
hydrochloric acid, HCl, (0.1 mol dm^{-3})
sodium carbonate, Na_2CO_3, (1.0 mol dm^{-3})
universal indicator solution

Method

See pupils' sheet.

Chemical background

Sodium carbonate produces carbon dioxide with acid which helps to mix the solution and assist the sodium hydroxide in neutralising the acid.

The densities of the liquids are different and the diameter of the burette slows down the mixing so that the rainbow layers will persist for several days.

9: Smell Molecules - Ancient and New!


eye protection must be worn


CORROSIVE concentrated sulphuric acid ethanoic acid butanoic acid


HIGHLY FLAMMABLE alcohols and esters

● Basic level ● 30-60 minutes to prepare esters (teacher)
● 30 minutes to carry out (pupils)

Requirements

access to a fridge
gelatin
small pieces of absorbent card
glass dishes to place cards in
clean pipettes for dispensing esters

A. TO MAKE FRUIT SMELLING ESTERS
(TO BE CARRIED OUT BY TEACHER):
'isoamyl' alcohol (a mixture of isomers of pentanol)
ethanol
phenylmethanol
propan-1-ol
ethanoic acid
butanoic acid
concentrated sulphuric acid
small tubes with bungs for ester samples

B. AND C.
oils of jasmine, lily of the valley, apple, heliotrope, peppermint (available from chemists and aromatherapy outlets)

Method

To make small amounts of each ester:

1. Use 5-10 drops of undiluted acid with 5-10 drops of the alcohol in a boiling tube.
2. Add 1-2 drops of concentrated sulphuric acid.
3. Warm gently for about five minutes.
4. Cool down under a tap and then add the mixture to 5 cm^3 of 1 mol dm^{-3} sodium carbonate solution to neutralise the concentrated acid. Store in small tubes with bungs.
5. Dispense 1-2 drops only, on to pupils' cards.

The table below shows the combinations needed to make a range of esters :

Alcohol	Hazard	Acid	Hazard	Ester produced	Smell	Hazard
'isoamyl' (a mixture of isomers of pentanol)	highly flammable harmful	ethanoic	corrosive	'isoamyl' ethanoate	banana	highly flammable
ethanol	highly flammable	butanoic	corrosive	ethyl butanoate	pineapple	highly flammable
phenyl-methanol	harmful	ethanoic	corrosive	phenylmethyl ethanoate	peaches	highly flammable
propan-1-ol	highly flammable	ethanoic	corrosive	1-propyl ethanoate	pears	highly flammable

For rest of procedure see pupils' sheet.

Safety advice

Do not provide pupils with more than 1-2 drops of each ester unless they are age 14 or older.

Chemical background

Esters are produced by the combination of alcohols and acids in an esterfication reaction.

ethanol + ethanoic acid ⟶ ethyl ethanoate + water

Many of the natural flavours and smells of flowers and fruits result from the presence of volatile esters.

A substance has a smell because its molecules can excite the nerve endings in the nose. The nervous system is in direct contact with the outside world through the sense of smell. It is thought that molecules of a smelly substance interact with a protein molecule in the nerve endings and hence stimulate the nerve cell to send a message to the brain. The smell molecule has to be a particular shape to fit a particular olfactory site and so trigger a nerve impulse.

eye protection must be worn

HIGHLY FLAMMABLE ethanol

10: T-Shirt Chromatography

- **Basic level**
- **30 minutes to prepare; at least 30 minutes to run chromatogram (preferably longer)**

Requirements

access to a fume cupboard
T-shirt, pre-washed (preferably white & 100% cotton)
large plastic bag
permanent felt-tip pens
4 dm^3 glass beaker or similar container

eye protection
disposable plastic gloves (to protect hands from staining)

ethanol
textile medium (optional) available from haberdashery stores (this fixes the dye)

Method

See pupils' sheet.

Chemical background

The ink dyes are separated out as they pass through the cotton of the T-shirt and are carried along by the ethanol solvent. The separation depends on the differing solubility of the dyes in ethanol and their differing affinity for the cotton fibres.

11: Cooking is Chemistry!


do not eat any food in, or prepared in, a laboratory


uncooked eggs may be contaminated with *Salmonella*

● **Basic/intermediate level** ● **French dressing 30 minutes**
● **Mayonnaise 30-60 minutes**

Requirements

FRENCH DRESSING
10 cm^3 vinegar
20 cm^3 cooking oil
a jar with a tight lid
a magnifying glass

MAYONNAISE
2 egg yolks
300 cm^3 cooking oil
30 cm^3 vinegar
small bowl
whisk

Method

See pupils' sheet.

STRAWBERRY BOMBE
Ice cream, bombes and other frozen desserts contain water and cream. Separation of the fat is not a problem, because the fat droplets are very small. In frozen desserts, the problem is to keep the water droplets small. Large water droplets form large ice crystals and give the dessert a grainy texture. As long as the ice crystals are tiny, the dessert will be smooth.

Safety advice

Do not allow pupils to eat anything which has been produced in the lab. They could do these experiments at home but you must obtain written permission from their parents or guardians (see page 13).

Chemical background

Many substances can act as emulsifiers for oil-water interfaces. Detergents perform this function in the context of washing and stain removal. In the context of food, one of the most common emulsifiers is lecithin, a phospholipid present in egg yolk. In its pure form lecithin is identified by its E number (E322) in ingredients lists.

In the Strawberry Bombe the gelatin keeps water droplets from coming together to make large ice crystals in the frozen mixture which alters the texture of the Bombe.

12: Dyeing Your Eggs


eye protection must be worn


Salmonella in eggs

● **Basic/intermediate level** ● **Under 30 minutes to prepare**
● **30 minutes for straightforward dyeing; scope for longer investigations**

Requirements

250cm^3 beakers
measuring cylinder or pipette to dispense 10 cm^3

eggs - preferably hard boiled
ethanoic acid (colourless vinegar will do), (1.0 mol dm^{-3})

eye protection

food colouring such as:
Erythrosine, Allurs Red, Sunset Yellow, Brilliant Blue, Fast Green (all are available in any food shop)

marble chips, $CaCO_3$
sodium chloride, NaCl

Method

See pupils' sheet.

Safety advice

Use hard-boiled eggs to eliminate risk of *Salmonella*.

Chemical background

The chemical ideas behind the process involve some complex chemistry of dyes but that should not preclude younger students from carrying out an investigation.

It is necessary to consider both the chemical composition of eggshells and the structure of the dyes in food colours.

Chicken eggshells consist of approximately 95% calcite, a crystalline form of calcium carbonate ($CaCO_3$) and a sparse protein matrix that binds the calcite. The shell surface is a covered by a coating of 90% protein called the cuticle.

The food dyes are classified as anionic or acid dyes. These are direct dyes and chemically bond to surfaces with cationic sites through salt linkages - much like the interaction between anionic direct dyes and cationic sites ($-NH_3^+$ groups) of the protein structure in wool or silk.

More dye absorbs to the eggshell as the pH decreases. More amino acid groups are protonated providing more cationic sites as the pH decreases.

Marble chips do not react with the dyes - the protein surrounding the egg has a large effect on the dyeing.

Adding salt retards the absorption of the dye on to the eggshell.

13: Fire Writing

- **Basic/intermediate level**
- **Under 30 minutes to prepare; 30 minutes to carry out**

Requirements

weighing balance
matches
10 cm^3 measuring cylinder
50 cm^3 beaker
stirring rod
filter paper (or large chromatography sheets or paper towels cut in half)
wooden taper
small paint brush or wooden taper
pencil
10 g sodium nitrate
eye protection

Method

See pupils' sheet.

Safety advice

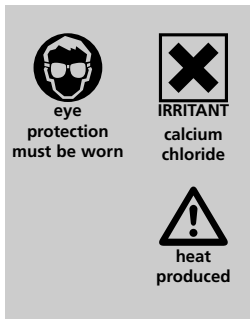
Sodium nitrate (solid) is an oxidising agent.
Instruct pupils not to touch the burning paper.
If a hairdryer is used (see pupil's sheet) ensure that it has been through your education employer's electrical test procedure.

Chemical background

$$2NaNO_3(s) \xrightarrow{HEAT} 2NaNO_2(s) + O_2(g)$$

This reaction produces enough oxygen to keep the treated paper smouldering.

14: Handwarmers



● Basic/intermediate level ● 30-60 minutes

Requirements

weighing balance
150 cm^3 beaker
250 cm^3 measuring cylinder
0°C-100°C thermometer
stirring rod
spatula
2 sealable freezer bags - large and small

calcium chloride, $CaCl_2$, 8 mesh

eye protection

Method

See pupils' sheet.

Chemical background

When the bag is broken, the water dissolves the solid $CaCl_2$.

$$CaCl_2(s) \longrightarrow Ca^{2+}(aq) + 2Cl^-(aq)$$

The energy transferred is 747J per gram of dissolved $CaCl_2$.
The solubility of $CaCl_2$ ranges from 64.5 g/100 cm^3 at room temperature to 159 g /100 cm^3 at 100°C.

YOU CAN MAKE THIS ACTIVITY INTO AN INVESTIGATION. The task is:
'You are working for a company who want to develop a heat pack. Each pack is to contain 100 cm^3 of water. Your job is to determine how much calcium chloride must be present in a heat pack to achieve a maximum temperature of 40°C-50°C.'

15: One-Pot Copper Reactions

● Basic/intermediate level
- only suitable for age 13-14 and upwards
● 30 minutes to prepare; 30 minutes to carry out

Requirements

100cm^3 of each solution will be enough for at least five one pot reactions.

Solutions of:
copper nitrate, $Cu(NO_3)_2$ (0.1 mol dm^{-3})
ammonia solution, NH_3 (aq) (3.0 mol dm^{-3})
sodium sulphide, Na_2S (1.0 mol dm^{-3})
potassium iodide, KI (1.0 mol dm^{-3})
sulphuric acid, H_2SO_4 (0.1 mol dm^{-3})
de-ionised water

sodium hydroxide, NaOH (1.0 mol dm^{-3})
hydrochloric acid, HCl (1.0 mol dm^{-3})
sodium carbonate, Na_2CO_3 (0.2 mol dm^{-3})
sodium thiosulphate, $Na_2S_2O_3$ (0.5 mol dm^{-3})
hydrogen peroxide, H_2O_2 (3%)

50 cm^3 or 100 cm^3 beaker
disposable pipettes

Method

See pupils' sheet.

Safety advice

Note that this experiment requires 1.0 mol dm^{-3} sodium hydroxide and most education employers would only consider it suitable for age 13-14 upwards. Supervise the use of disposable pipettes as two of the solutions are corrosive.

Chemical background

1. $Cu^{2+}(aq)$ – light blue colour
2. When the sodium carbonate is added the following reactions occur:
   The carbonate reacts with water: $CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq)$
   Copper ions form insoluble $Cu(OH)_2$ by precipitation: $Cu^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Cu(OH)_2(s)$
3. When the hydrochloric acid is added the reactions are:
   $CO_3^{2-}(aq) + 2H^+(aq) \rightleftharpoons CO_2(g) + H_2O(l)$
   $Cu(OH)_2(s) + 2H^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2H_2O(l)$
   Vigorous bubbling as CO_2 is produced. Copper hydroxide goes back into solution.
4. When sodium hydroxide is added solid copper hydroxide reforms:
   $Cu^{2+}(aq) + 2OH^-(aq) \rightleftharpoons Cu(OH)_2(s)$
5. When sulphuric acid is added copper hydroxide dissolves:
   $Cu(OH)_2(s) + 2H^+(aq) \rightleftharpoons Cu^{2+}(aq) + 2H_2O(l)$
6. When potassium iodide is added the iodide ion reduces Cu^{2+} to Cu^+, while iodine is produced:
   $2Cu^{2+}(aq) + 2I^-(aq) \rightleftharpoons 2Cu^+(aq) + I_2(aq)$
   Cu^+ forms CuI by precipitation:
   $Cu^+(aq) + I^-(aq) \rightleftharpoons CuI(s)$
   The overall effect is a precipitate of CuI (white) against a brown solution of iodine.
7. When sodium thiosulphate is added brown coloration of iodine is removed by the thiosulphate ion as the iodine is reduced back to iodide ions. White CuI precipitate remains.
   $I_2(s) + 2S_2O_3^{2-}(aq) \rightleftharpoons 2I^-(aq) + S_4O_6^{2-}(aq)$
8. When ammonia is added copper iodide dissolves in excess ammonia as the Cu^+ ion forms a complex with ammonia.
   $CuI(s) + 2NH_3(aq) \rightleftharpoons Cu(NH_3)_2^+(aq) + I^-(aq)$
9. H_2O_2 oxidises the copper(I) ion into copper(II), then ammonia forms a further complex with Cu^{2+}.
   $2Cu(NH_3)_2^+(aq) + H_2O_2(aq) + 4NH_3(aq) \rightleftharpoons 2Cu(NH_3)_4^{2+}(aq) + 2OH^-(aq)$
10. Finally when sodium sulphide is added a precipate of copper(II) sulphide is formed:
    $Cu(NH_3)_4^{2+}(aq) + S^{2-}(aq) \rightleftharpoons CuS(s) + 4NH_3(aq)$


eye protection must be worn


HIGHLY FLAMMABLE ethanol


HARMFUL copper sulphate


IRRITANT iron(III) nitrate

16: Secret Writing

- **Basic/intermediate level**
- **30-60 minutes to prepare; 30 minutes to carry out**

Requirements

weighing balance
spray bottles (plastic spray bottles from a garden centre are ideal)
pin board for attaching paper to be sprayed, pins
small paint brushes
large sheets of chromatography paper
hairdryer (optional)

eye protection
disposable gloves (optional)

de-ionised water
5 g potassium hexacyanoferrate(II), $K_4[Fe(CN)_6].3H_2O$
5 g copper sulphate, $CuSO_4.5H_2O$
5 g ammonium thiocyanate, NH_4SCN
5 g iron(III) nitrate, $Fe(NO_3)_3$
100 cm^3 ammonia solution, NH_3 (aq), (0.2 mol dm^{-3})
phenolphthalein solid
ethanol

Method

Advance preparation of solutions for pupils:

1. Dissolve 0.1 g phenolphthalein in 60 cm^3 ethanol (highly flammable) and make up to 100 cm^3 with de-ionised water (this is your bench solution).
2. Dissolve all the other solids in 100 cm^3 de-ionised water.
3. Put solutions of iron nitrate and ammonia into separate, labelled, spray bottles.
4. Adjust the nozzle on each spray bottle to give a fine mist and spray several times to ensure that the spray contains solution.

The pupils follow the procedure on the pupils' sheet.

Safety advice

Make sure that pupils avoid spraying their hands (or they can wear disposable gloves) and wash their hands afterwards.
If a hairdryer is used (see pupils' sheet) ensure that it has been through your education employer's electrical test procedure.

Chemical background

'ink'	spray solution	colour produced
potassium hexacyanoferrate	iron nitrate	dark blue (Prussian blue)
ammonium thiocyanate	iron nitrate	red-brown (iron-thiocyanate complex)
copper sulphate	ammonia	vivid blue copper ammine complex
phenolphthalein	ammonia	pink (pH indicator)

17: The Apothecary's Cocktail Three Layer Liquid

- **Basic/intermediate level**
- **Setting up the intermediate stage takes less than 30 minutes**
- **Final stage needs to be left for several hours**

eye protection must be worn

HARMFUL dimethyl-benzene (xylene) copper sulphate

HIGHLY FLAMMABLE ethanol

Requirements

1 dm^3 measuring cylinder
500 cm^3 conical flask and bung
500 cm^3 measuring cylinder
filter paper
filter funnel

eye protection

potassium carbonate, K_2CO_3
copper sulphate, $CuSO_4$
ethanol
paraffin oil
dimethylbenzene (xylene) - dyed with Sudan III

Method

See pupils' sheet.

Chemical background

Multiple layers are produced due to the different densities and limited miscibility of the liquids.

The differing solubilities of suitable dyes or coloured salts in the various solvents make the formation of layers separated by phase boundaries very clear.

An investigation of alternative dyes that produce a similar three-layer effect is a possible extension of this experiment.


eye protection must be worn


HARMFUL copper sulphate crystals and solution (>1.0mol dm^{-3})


wear gloves when using nickel or cobalt compounds

nickel sulphate crystals and solution (>0.5mol dm^{-3})

cobalt chloride crystals and solution (>1.0mol dm^{-3})

18: A Magic Box

● Intermediate level
● 30 minutes to prepare; 30 minutes to carry out

Requirements

weighing balance
spatulas
cardboard box - shoe box or similar
pestle and mortar
fine paint brush
pen with steel nib
crystallising dish
2 sheets of absorbent paper
100 cm^3 measuring cylinder
150 cm^3 beaker
copper sulphate crystals, $CuSO_4$
ammonia solution, NH_3, 3%
OPTIONAL:
cobalt chloride, $CoCl_2$
nickel sulphate, $NiSO_4$

disposable gloves (for use with nickel and cobalt compounds)
eye protection

Method

See pupils' sheet.

Safety advice

Ensure that pupils wear eye protection.

Nickel compounds can cause sensitisation, avoid exposure to dust. Pupils younger than 13 years old should not use nickel sulphate solution. Wear gloves if the concentration exceeds 1.0mol dm^{-3}. Take similar precautions with cobalt salts.

Chemical Background

The parts of the picture painted with blue $CuSO_4$ 'ink' turn deep blue. This is because Cu^{2+} ions from the $CuSO_4$ react with the ammonia gas to form a complex of $[Cu(NH_3)_4]^{2+}$ ions which are dark blue.

The writing turns a shiny copper colour. Metallic copper is deposited on the paper as well as the nib itself when the steel pen is used. This is because the Cu^{2+} ions oxidise the iron to Fe^{2+} (aq) ions and are reduced to Cu(s).

You may suggest using other transition metal salt solutions to develop different coloured inks. Cobalt chloride (which is the safer of the two) and nickel sulphate will work too (but see Safety advice above).


eye protection must be worn


IRRITANT calcium chloride


fine dust


OXIDISING do not use nitrates


HARMFUL copper oxide

19: Burning Food

● Intermediate level ● 30 minutes total

Requirements

glass funnel
long piece of rubber tubing (borrow from a Bunsen)
disinfectant
2 Bunsen burners
2 clamp stands
heat proof mats
spatula
newspapers
a variety of powdered food substances (e.g. custard powder, hot chocolate, flour, etc.)

safety screens
eye protection

OPTIONAL - FOR TEACHER ONLY DEMONSTRATION OF METAL FLAME TESTS
strontium chloride, $SrCl_2$, potassium chloride, KCl, sodium chloride, NaCl,
calcium chloride, $CaCl_2$, copper oxide, CuO

Method

See pupils' sheet.

Safety advice

Ensure that sufficient safety screens are used to protect experimenter and observers.
Restrict the quantity of food burned to one spatula measure.
Fine dust may irritate asthma sufferers.
This activity must be supervised very closely as pupils can become over-enthusiastic.

Chemical background

When food is burned in this way the stored energy is released very dramatically.

The finely powdered state of most of the foods and their large surface area will increase the rate of the reaction. The vigour of the reaction will also be affected by the calorific value of the food (compare fats and sugars).

After observing a teacher demonstration of metal flame tests the pupils could use this knowledge when

examining the listed contents on the food packets and interpreting the flame colours of burning foods.

Most foods burn with a yellow/orange flame which is linked to their sodium content.

20: Chemistry in the 23rd Century

● Intermediate level ● 60 minutes

eye protection must be worn

ensure that the pupils' plans are safe before you allow them to proceed

A. Battery Enterprise

Requirements

voltmeters, crocodile clips and leads

carbon electrodes in pencils, metals available in the kitchen, cutlery etc,
copper pipe off-cuts, aluminum foil
sodium chloride, NaCl
washing powder
vinegar, lemonade, lemons

The purpose of the activity is to produce the most appropriate combination of metals and electrolyte to produce a good voltage.

Safety advice

Do not allow your pupils to use bleach. You must check their plans before they proceed.

B. Chemical Power

Requirements

sodium hydrogencarbonate, NaHCO3, 5 g per pupil or working group
citric acid, 15 g per pupil or working group
100 g mass which will represent the 'dilithium crystal'

In addition to general lab equipment pupils should have access to assorted 'junk' e.g. plastic lemonade bottles, plastic bags, metal drink cans etc.

You may need to point out that they will need to add water to make the substances react to produce CO2.

An alternative procedure can be performed with half the quantities stated in the Pupil Worksheet.


eye protection must be worn

C. Dr Who's Sherbet Mixture

● Intermediate level ● 30-60 minutes total

Method

Each student should be given 20 g citric acid and 30 g sodium hydrogencarbonate and have access to a thermometer. You may need to tell them to add a few drops of water.

Chemical Background

With the right mixture the endothermic reaction which takes place can lower the temperature to -10°C.


eye protection must be worn


exothermic reactions
hydrochloric acid and magnesium can spit


EXPLOSIVE
hydrogen gas


FLAMMABLE
magnesium filings


IRRITANT
hydrochloric acid

21: Hydrogen Balloons

● Intermediate level ● 30 minutes total

Requirements

small plastic food bags or a bag of round balloons
boiling tubes and rack
pipette or similar to dispense 5 cm^3 - 10 cm^3 of acid
spatulas
sellotape
cotton
newspaper
elastic bands

magnesium filings, Mg
hydrochloric acid, HCl, (1 mol dm^{-3})

eye protection

Method

See pupils' sheet. Five boiling tubes of gas are generally sufficient to fill a bag or balloon.

Safety advice

Do not use magnesium powder. The reaction between magnesium and hydrochloric acid is very exothermic. Pupils will need strict supervision to prevent them sprinkling magnesium dangerously in a Bunsen flame.


eye protection must be worn


IRRITANT
ammonia solution
hydrochloric acid


wear gloves when you remove the silver fractals immediately after the experiment using a piece of filter paper


see cautionary note

22: Silver Fractals

● Intermediate level
● Under 30 minutes to prepare; 30 minutes to carry out

Requirements

overhead projector
petri dish, 15 cm diameter, 2 cm depth
power pack (range up to 22 V)
stands/clamps/boss head
2 paper clips
filter paper
250 cm^3 measuring cylinder

silver nitrate solution, $AgNO_3$, (0.1 mol dm^{-3})
ammonia solution, NH_3 (aq), (3.0 mol dm^{-3})
dilute hydrochloric acid, HCl, (2.0 mol dm^{-3})

eye protection

Method

See pupils' sheet.

Safety advice

Ensure that pupils use eye protection at all times.

Wear gloves while you remove the silver fractals immediately after the experiment using a piece of filter paper. You can re-use the silver.

CAUTION!
Explosive silver fulminate, Ag_3N, may form after a few hours. To dispose of the silver nitrate add 10 cm^3 5mol dm^{-3} hydrochloric acid and reduce to metallic silver by means of zinc rods or granules.

Chemical background

The silver ions are reduced to metallic silver during electrolysis.

$$Ag^+(aq) + e^- \longrightarrow Ag(s)$$

23: Slime with a Twist

● Intermediate level ● 30 minutes to prepare
● 30-60 minutes to carry out

eye protection must be worn

UV source

Requirements

weighing balance
100 cm^3 measuring cylinder
250 cm^3 beaker
disposable pipettes
hot plate
stirring rod
source of ultraviolet light

eye protection

40 g poly(ethenol) (polyvinyl alcohol, PVA) $M_r = 65 \times 10^3$ or 115×10^3
4.0 g sodium tetraborate (borax) $Na_2B_4O_7.10\ H_2O$
0.40 g sodium fluorescein
0.10 g bromophenol blue

Method

SLIME
Advance preparation. These solutions will be sufficient to prepare ten 100 cm^3 portions of slime.

1. Add 4.0 g of sodium tetraborate to 100 cm^3 of water and warm slightly. Place in a labelled container.
2. Add 0.4 g of sodium fluorescein and 0.10 g of bromophenol blue to 1 dm^3 of distilled water. Label and set aside until you are ready to use it.

See pupils' sheet for further details of making the slime.

PUTTY
PVA glue from a chemical supplier produces a better result than cheaper `craft' glue.

Safety advice

Eye protection must be worn.

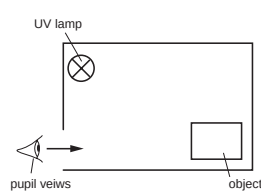
Pupils must not use the UV source themselves. If short wavelength UV (less than 315 nm) is used do not view directly.

It is best to mount the UV lamp in a box with a hole, so that the lamp cannot be viewed directly - only by reflected light.

Chemical background

The poly(ethenol) chains are linked by the borate groups through hydrogen bonding. The cross linking can break and reform easily. Most of the space within the gel is taken up by water molecules.

The sodium fluorescein fluoresces in the green region of the spectrum. The electrons in the fluorescein absorb light from the blue - ultraviolet end of the spectrum and emit this energy as they relax in the green region. Green light is seen on the incident side. The bromophenol blue absorbs the remaining regions of visible light except for the red end. This allows the red light to pass through the slime and be visible on the side the light exits from.



24: Chemical Problems to Solve

- **Intermediate/high level**
- **Under 30 minutes to prepare; 30 - 60 minutes to carry out**

Introduction

The pupils will have to arrive at their own method.
You MUST check the safety and viability of their method before you allow them to start.


eye protection must be worn

A. Removing Copper
Requirements

Each pupil should start with 150 cm^3 of copper sulphate solution, $CuSO_4$ (0.1 mol dm^{-3}) divided equally between three beakers.

Electrolysis equipment on request: Two leads, crocodile clips, electrodes, power packs or 6 V batteries.

Zinc granules on request.

Solid sodium carbonate, Na_2CO_3, on request.

Safety advice

Pupils should wear eye protection.
Copper compounds are harmful when solid or in moderately concentrated solution.

You MUST check the safety and viability of their method before you allow them to start.

Chemical background

Pupils should be aware that the blue colour is due to the presence of copper ions. They could suggest removal by:

i. Electrolysis.
ii. Precipitation with sodium carbonate followed by filtration.
iii. Displacement by zinc followed by filtration.


eye protection must be worn


HARMFUL solid copper compounds and moderately concentrated solutions


take care when evaporating

B. Black and White solids
Requirements

Each pupil should start with 100 cm^3 of copper sulphate solution, $CuSO_4$ (0.1 mol dm^{-3})

Solid sodium carbonate, Na_2CO_3, on request.

Safety advice

Pupils should wear eye protection.
Solid copper compounds and moderately concentrated solutions are harmful.
Care should be taken during evaporation to dryness to prevent spitting.

You MUST check the safety and viability of their method before you allow them to start.

Chemical background

Making black powder:

Add sodium carbonate to copper sulphate. The pale blue gelatinous precipitate of copper hydroxide, $Cu(OH)_2$, can be recovered by filtration. It will decompose on heating to produce black copper oxide, CuO.

Making the white powder:

The copper sulphate solution can be evaporated to dryness producing white anhydrous copper sulphate powder.

25: Clock Reactions


CORROSIVE
sulphuric acid


IRRITANT
hydrogen peroxide

- **Intermediate/high level**
- **30-60 mins to set up and time rates of reaction**
- **30-60 mins to develop the trick**

Requirements

stop clock
5 x 600 cm^3 beakers
5 x 250 cm^3 beakers
100 cm^3 measuring cylinders
5 stirring rods
eye protection

stock solutions of : solution A: sodium thiosulphate solution, $Na_2S_2O_3$ (0.2 mol dm^{-3})
solution B: potassium iodide solution, KI (1.0 mol dm^{-3})
solution C: starch solution 1%
solution D: a mixture of: sulphuric acid, H_2SO_4 (0.2 mol dm^{-3})
and hydrogen peroxide, H_2O_2 (0.09 mol dm^{-3})

Method

Make up the stock solutions and label the volumetric flasks clearly.

SOLUTION A: SODIUM THIOSULPHATE SOLUTION
Dissolve 49.6 g of $Na_2S_2O_3.5H_2O$ in 600 cm^3 distilled water. Make the volume up to 1 dm^3 with more distilled water. This solution will start to decompose after a few days so you should make it up fresh.

SOLUTION B: POTASSIUM IODIDE
Dissolve 166 g of KI in 800 cm^3 of distilled water. Make the volume up to 1 dm^3 with distilled water.

SOLUTION C: STARCH SOLUTION
Bring 500 cm^3 of distilled water to the boil in a 1 dm^3 beaker.
In a clean beaker make a slurry of 10 g of starch in 20 cm^3 of distilled water.
Pour the slurry into the boiling water and boil for 5 minutes.
Place 450 g of ice or 450 cm^3 of very cold water in a 2 dm^3 beaker and pour the hot starch mixture into the 2 dm^3 beaker.
After the ice has melted, dilute the mixture to 1 dm^3. This solution should be made up fresh.

SOLUTION D: HYDROGEN PEROXIDE / SULPHURIC ACID SOLUTION
Add 100 cm^3 of 2.0 mol dm^{-3} sulphuric acid (corrosive) to a 1 dm^3 beaker and add 500 cm^3 of distilled water to this.
Add 100 cm^3 of 20 vol hydrogen peroxide solution (irritant) to the 1 dm^3 beaker.
Dilute the solution to 1 dm^3 by adding distilled water. (This solution is now 0.2 mol dm^{-3} H_2SO_4 and ~0.09 mol dm^{-3} H_2O_2 and is low hazard.)

See the pupils' sheet for the rest of the procedure.

Chemical background

The initial concentration of thiosulphate ions is varied and the clock period rate is varied. The sudden change from colourless to deep blue can be explained with the following sequence of equations:

In an acidic solution, iodide ions are oxidized by the peroxide to triodide ions:

$$\text{(i)}\ 3I^-(aq) + H_2O_2(aq) + 2H^+(aq) \longrightarrow I_3^-(aq) + 2H_2O(l)$$

The triodide ions are reduced back to iodide ions by the thiosulphate ions:

$$\text{(ii)}\ I_3^-(aq) + 2S_2O_3^{2-}(aq) \longrightarrow 3I^-(aq) + S_4O_6^{2-}(aq)$$

When all the thiosulphate ions have been used by the second reaction, triodide ions react with starch to from the blue starch-iodide complex.


eye protection must be worn


HARMFUL
copper sulphate
nickel sulphate


wear gloves

26: Electroplating Faces

● Intermediate/high level ● 30-60 minutes

Requirements

100 cm^3 beaker
2-4 V d.c. power supply, leads, crocodile clips

eye protection
disposable plastic gloves

copper electrolyte: copper sulphate, $CuSO_4$ (aq) (1.0 mol dm^{-3})
nickel electrolyte: nickel sulphate, $NiSO_4$ (aq) (1.0 mol dm^{-3})

foreign copper coin
copper foil for anode
foreign nickel coin
nickel foil for anode

Method

See pupils' sheet.

Safety advice

Nickel salt solutions should only be used by pupils aged 13-14 and older.

Nickel metal and solutions of nickel salts may cause sensitisation by skin contact so ensure that pupils wear gloves.

Chemical Background

At anode:

$$Ni(s) \longrightarrow Ni^{2+}(aq) + 2e^-$$

At cathode:

$$Ni^{2+}(aq) + 2e^- \longrightarrow Ni(s)$$

27: Strengthening Ice

● Intermediate/high level ● 30-60 minutes to prepare
● 1-2 days to freeze ● 30-60 minutes to test

Requirements

access to a freezer
ice trays
cotton wool
iron wool

straw (or any other material suggested by the group)
100 g masses - quite a few will be needed for strong material
string, or similar, for suspending 100 g masses from the ice cubes
some means of catching the masses when the ice breaks (e.g. polystyrene or other packaging)

Method

See pupils' sheet.

Chemical background

Composite materials have been used since the Pharaohs put straw in their bricks. The purpose of putting chopped plant fibres into Inca and Mayan pottery was exactly the same as for the Egyptian bricks: to prevent cracking when the wet clay was dried rapidly in the sun.

Small amounts of fibre do have a considerable effect in improving the strength and toughness of weak brittle materials. The project Max Perutz worked on was devised by an English scientist called Geoffrey Pyke. His original idea was to tow an iceberg into the Atlantic. However he soon found that natural ice is quite weak in tension. It is brittle and cracks spread easily. This is why icebreakers can sail through icebergs. Pyke strengthened the iceberg by adding wood pulp to his ice; cracks are stopped or deflected by the presence of fibres.

SOME USEFUL BACKGROUND READING:

J E Gordon The New Science of Strong Materials. Penguin Books
E N Ramsden Materials Science. Stanley Thornes Ltd.

28: Technicolour Fun
A. Technicolour Tubes

● Intermediate/high level
● Initial trial 30 minutes, can be extended


eye protection must be worn


ensure that the pupils' plans are safe before you allow them to proceed

You could provide a range of liquids like those used in The Apothecary's Cocktail.
You must check each one before you allow pupils to mix potentially reactive mixtures.

B. Creating Colour

● Intermediate level ● 30-60 minutes total


eye protection must be worn.


IRRITANT sodium hydroxide

Requirements

5cm^3 universal indicator
hydrochloric acid, HCl, (0.1 mol dm^{-3})
sodium hydroxide, NaOH, (0.1 mol dm^{-3})
Allocate a small amount of universal indicator to each pupil or group.

29: Create Your Own Chemistry Trail

● High level ● Long term project

See pupils' worksheet for useful references.

eye protection must be worn

IRRITANT
iron chloride solid and solution

30: Naples Blood

● High level ● 30-60 minutes to prepare ● Leave for 4 days

Requirements

weighing balance
dialysis tubing
150 cm^3 - 250 cm^3 beakers
100 cm^3 measuring cylinder

eye protection

10 g iron(III) chloride hydrate, $FeCl_3.H_2O$
20 g calcium carbonate powder, $CaCO_3$
1.5 g sodium chloride, NaCl

Method

See pupils' sheet.

Chemical background

A thixotropic gel is a viscous fluid which has set, but which becomes liquid if shaken, pressed or jarred - rather like tomato ketchup. Left to stand it sets again.

Thixotropy depends on a network of hydrogen bonds which is strong enough to support the bulk of the material when set, but easily collapsed by shock or pressure.