DEMONSTRATION 4.1

THE "COLD LIGHT" REACTION

This chemiluminescence demonstration shows that energy produced by a chemical reaction can be released as light.

EQUIPMENT

- 1 L conical flask
- 2 x 500 mL conical flasks
- glass tube coiled into a helix with funnel to fit
- retort stand
- boss head
- clamp

REAGENTS

- anhydrous sodium carbonate, Na_2CO_3 (2 g)
- luminol (1 g)
- ammonium hydrogencarbonate-1-water, $NH_4HCO_3 \cdot H_2O$ (0.25 g)
- copper(II) sulfate solution, $CuSO_4 \cdot 5H_2O$ (1 mL, 1 M)
- sodium hydrogencarbonate, $NaHCO_3$ (12.5 g)
- hydrogen peroxide, H_2O_2 (0.1%) (500mL)(Fresh)
- distilled water

PREPARATION

SOLUTION A

- Dissolve the sodium carbonate in 250 mL of distilled water.
- Add the luminol and stir until dissolved.
- Add ammonium hydrogencarbonate-1-water, sodium hydrogencarbonate , and the copper sulfate.
- When everything has dissolved, dilute to 500 mL.

SOLUTION B

- Add 1.6mL of 30% Hydrogen peroxide to 250mL of deionised water in a 500ml flask. Make up to 500mL and transfer the solution to a labelled dark bottle. If preparing a day before make sure to store the solution in the fridge.

PROCEDURE

- Dim the lights.
- Pour solutions A and B simultaneously into funnel attached to the glass helix.

RESULTS

When solutions A and B are poured simultaneously into the funnel, an eerie pale blue luminescence is emitted.

The luminescence is due to the luminol being converted to an excited-state product due to oxidation by the peroxide. This product then decays back to the ground state by emitting light. For equations, see Demonstration 4.2.

DEMONSTRATION 4.2

ENERGY CHANGE: CHEMILUMINESCENCE

This chemiluminescence demonstration shows that energy produced by a chemical reaction can be released as light.

EQUIPMENT A glass jar with a screw cap.

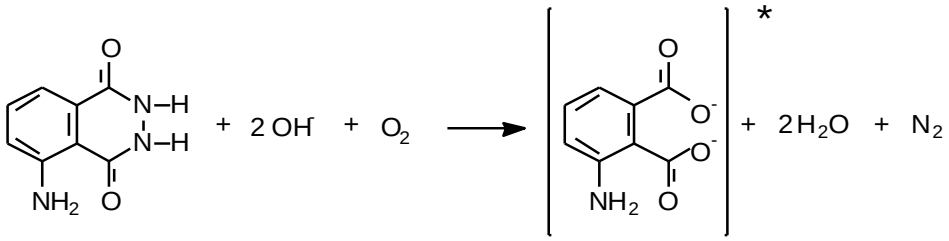
REAGENTS

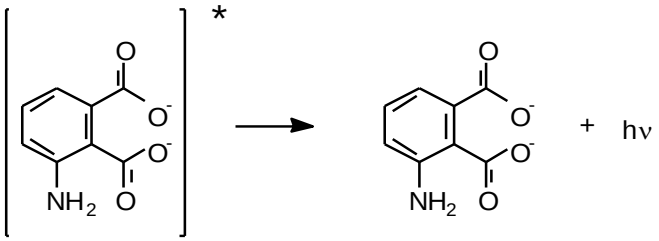
- potassium hydroxide, KOH (70 g)
- dimethyl sulfoxide, DMSO (60 mL)
- oxygen gas (from cylinder)
- luminol (0.1 g)

PROCEDURE

- Place potassium hydroxide (70 g) in the jar and add dimethyl sulfoxide (60 mL).
- Pass a stream of oxygen gas into the jar for a few seconds then cap the jar.
- To start the demonstration add luminol (0.1 g) and shake the jar gently for a few minutes.
- Pass the jar around the class.

RESULTS A brilliant blue luminescence which lasts half an hour is produced.
Note: Vigorous shaking will result in brighter luminescence for a shorter duration of time.
In this reaction DMSO acts as a solvent and the chemiluminescence results from the reaction of luminol with molecular oxygen. This is achieved by bubbling oxygen gas through the solution and enhanced aeration is obtained by shaking. The overall reaction is an oxidation reaction and is given by:





High Risk Demonstration: 1- Refer to HIRAC 2- Set up in Red Tray

DEMONSTRATION 4.3

DENSITY AND COMBUSTIBILITY: "STAR WARS"

This demonstration illustrates that hydrogen is less dense than air and that it will burn in air.

EQUIPMENT

- hydrogen gas cylinder (with appropriate regulator)
- rubber hose with glass funnel in one end
- 2 m long pole
- taper
- adhesive tape
- matches
- crystallising dish (about 15 cm diameter)
- retort stand
- boss head and clamp
- liquid soap or detergent.

PREPARATION

- Fill the crystallising dish with warm water.
- Add soap.
- Set up the hydrogen cylinder and attach hose and funnel.
- Using the retort stand and clamp secure the funnel so that it dips below the surface of the soap solution.
- Attach the taper to the tip of the pole with adhesive tape.
- Provide matches.

PROCEDURE

- Pass a steady stream of hydrogen gas into the soap solution.
- When a sufficiently large number of soap bubbles has formed, aggregates of them will break away from the surface and float upwards.
- Light the taper.
- Dim the lights and ignite the bubble aggregates before they reach the ceiling.

CAUTION **!**

The explosions should take place at a distance of about 3 m from the basin, the hydrogen cylinder and the nearest member of the audience. At least two consecutive bubble aggregates should be allowed to drift away without ignition.

Experience has shown that the first bubble aggregates, if ignited, will explode with alarming violence as they contain a mixture of hydrogen and air.

It is essential to keep the lighted taper well clear of the basin at all times. This was not done on one occasion. "Premature ignition" took place in the basin and, for one moment, it seemed as if the entire lecture theatre was going to be launched skyward.

RESULTS

The hydrogen gas contained in the bubbles will ignite and burn with a bright orange-yellow light. The equation for the reaction is:

$2H_2(g) + O_2(g) \zeta 2H_2O(g)$.

High Risk Demonstration: Refer to HIRAC. Set up in Red Tray

DEMONSTRATION 4.4

THE METHANOL CANNON

The explosive combustion of methanol is demonstrated.

EQUIPMENT

- plastic bottle
- 2 long nails
- retort stand with clamp
- tight fitting cork
- induction coil with leads

REAGENTS

- methanol, CH_3OH (10 mL)

PREPARATION

- Clean the metal nail tips with emery paper.
- Prepare the "cannon" by inserting two large nails into the sides of a heavy plastic bottle. The points of the nail should be separated by about 1cm
- Add methanol (about 10 mL) to the bottle.
- Shake the bottle to vaporise and distribute the methanol.
- Discard excess.
- Place a tight-fitting cork in the mouth of the bottle.
- Securely fasten the bottle to the retort stand by clamping the neck of the bottle with the clamp attached to the retort stand.

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PROCEDURE

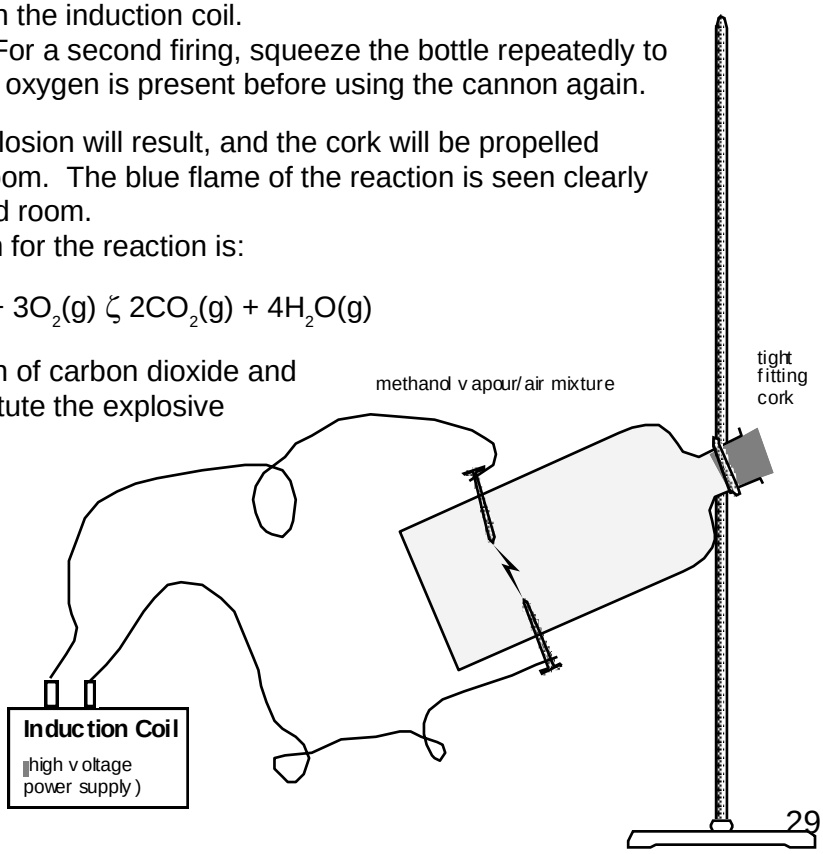
- Attach the leads from the induction coil to the ends of the nails.
- Direct the mouth of the bottle up and away from the audience.
- Dim the lights.
- Turn on the induction coil.
  Note: For a second firing, squeeze the bottle repeatedly to ensure oxygen is present before using the cannon again.

RESULTS

A **LOUD** explosion will result, and the cork will be propelled across the room. The blue flame of the reaction is seen clearly in a darkened room.
The equation for the reaction is:

$$2CH_3OH(g) + 3O_2(g) \zeta 2CO_2(g) + 4H_2O(g)$$

The evolution of carbon dioxide and steam constitute the explosive force.



DEMONSTRATION 4.5

COMPARISON OF THE COMBUSTION PROPERTIES OF VARIOUS GASES

The difference in explosive properties of hydrogen, hydrogen/oxygen mixture and helium is demonstrated by igniting a balloon of each gas.

EQUIPMENT

- 3 spherical balloons, about 30 cm diameter
- long pole
- taper and matches
- cotton thread and adhesive tape
- 3 gas cylinders with regulators: hydrogen, helium and oxygen
- retort stand and retort ring
- wooden stool
- safety glasses
- head phones
- felt tip pen

PREPARATION Immediately before the demonstration, fill the balloons as follows:

- all helium.
- all hydrogen.
- about 1 part hydrogen and 2 parts oxygen. **The gases are not to be mixed in the stoichiometric ratio as this produces too violent an explosion.** The balloon must not float after filling and must fit inside a 5 L beaker to ensure that not too much gas is ignited.
- Using felt pens mark the balloons with: “He”, “H_2”, “O_2/H_2” .
- Secure the balloons to the lecture bench as follows:
- Ensure the greatest possible distances between each balloon, but at least 2 metres.
- Using cotton thread, tie the helium and the hydrogen balloons to a fixture so that they float at least 2 metres above the bench top.
- Attach the retort ring to the top of the retort stand.
- Rest the balloon filled with hydrogen and oxygen on the ring and secure it with thread.
- Place a stool on the bench top and put the retort stand on top of the stool.

CAUTION

Ensure that the balloons are well removed from glass fixtures such as lights and windows.

Supply the pole, matches, safety glasses and ear plugs.

PROCEDURE Observe the following guidelines carefully:

CAUTION **The light emitted is sufficiently bright to be potentially dangerous to the eyes. Therefore, the explosions must not be set off in total darkness. The audience must be warned not to look directly at the balloons. Be aware that hot rubber might fly in all directions. Ensure that members of the audience are at a safe distance.**

- Put on safety glasses and ear plugs.
- Dim room lights and light the taper.
- Touch the flame to each balloon in the following order:

  helium
  hydrogen
  hydrogen/oxygen

RESULTS

Helium: does not burn; noise-output is merely that of an inflated balloon bursting

Hydrogen: explodes with a yellow-orange light and loud noise.

Hydrogen/oxygen mixture: explodes with a blinding flash and a terrifying noise.

DEMONSTRATION 4.6

ENTHALPY OF SOLUTION OF AMMONIUM CHLORIDE: CHEMICAL COLD PACK

Water is added to a flask containing ammonium nitrate and a small amount of blue food dye. The temperature of the resultant solution is seen to drop rapidly.

EQUIPMENT

- 500ml conical flask with stopper
- Thermometer and Temperature probe (optional)
- light box
- stirring rod
- towel

REAGENTS

- Ammonium Chloride, NH_4Cl (150 g)
- blue food dye

PREPARATION

- Add ammonium chloride (150 g) and a few crystals of blue food dye to 500ml conical flask.
- Stopper the flask.

PROCEDURE

- Place conical flask on the light box.
- Add water to the flask and stir to mix.
- Put the thermometer probe into the flask.
- Pass it around the class wrapped in a towel.

RESULTS

When water is added the ammonium nitrate dissolves. Heat is absorbed from the surroundings during the solution process thereby lowering the temperature.

DEMONSTRATION 4.7

ENTHALPY OF SOLUTION OF CALCIUM CHLORIDE: CHEMICAL HOT PACK

Water is added to a conical flask containing calcium chloride and a small amount of a red dye. The temperature of the resultant solution is seen to increase rapidly.

EQUIPMENT

- 500ml conical flask with stopper
- Thermometer or Temperature probe (optional)
- light box
- stirring rod
- towel

REAGENTS

- calcium chloride, $CaCl_2$ (150g)
- Any food colouring

PREPARATION

- Add calcium chloride (150 g) and a few drops of the food colour to the conical flask.
- Stopper the flask.

PROCEDURE

- Place conical flask on the light box.
- Add water to the flask and stir to mix.
- Put the thermometer probe into the flask.
- Pass it around the class wrapped in a towel.

RESULTS

When the contents in the flask are mixed a considerable temperature increase is observed.

CAUTION ! **The reaction produces sufficient heat to cause burns.**

High Risk Demonstration:

- **Refer to HIRAC**
- **Set up in Red Tray**

DEMONSTRATION 4.8

ENTHALPY OF PHASE CHANGE:
CRYSTALLISATION OF SUPERSATURATED SODIUM ACETATE

A supersaturated solution is made to crystallise by adding a "seed" crystal. The crystallisation process evolves heat.

EQUIPMENT

- 3 L conical flask
- digital thermometer and probe (optional)
- hot plate
- aluminium foil
- tweezers
- watchglass

REAGENTS

- sodium acetate-3-water, $NaC_2H_3O_2{\cdot}3H_2O$ (1000 g)
- water (400 mL)

PREPARATION

- Place the sodium acetate in the flask.
- Add the water and slowly warm the flask to boiling.
- Swirl the flask until the solid dissolves, washing any solid remaining on the neck or sides down with a small amount of water.
- Ensure that the solution is completely clear at ambient temperature.

If re-crystallisation should occur:

- Add a small amount of water and re-heat the solution slowly until the crystals have just disappeared.
- Wrap the flask in foil and allow to cool.
- If necessary, repeat this procedure until the solution remains clear on having cooled.
- Do not disturb.
- Seal well.

Note: This solution may be re-used indefinitely, provided it remains sealed and is never allowed to heat up much beyond the point at which the solid dissolves.

If a previously prepared solution is to be re-used, immerse the flask containing the crystallised solution in hot water. As soon as the solution turns clear, remove the flask from the bath. Allow to cool without disturbance.

- Carefully place the flask on the light box.
- Provide tweezers and some crystals of sodium acetate.

PROCEDURE

- Remove the foil from the flask.
- "Seed" the supersaturated solution by adding a small crystal of sodium acetate to the beaker.
- Place the thermometer probe near the flask.

RESULTS

After a few seconds, large white crystals will grow in the beaker and the flask will get hot.

DEMONSTRATION 4.9

ENTHALPY OF NEUTRALISATION: SODIUM HYDROXIDE AND HYDROCHLORIC ACID

The addition of water to acid, water to base and acid to base yields a range of temperatures, illustrating the difference in the enthalpies of dilution and neutralisation.

EQUIPMENT

- Thermometer or Temperature probe
- 3 x 300 mL beakers (tall-form preferable)
- 3 x 100 mL graduated cylinders
- 3 x stirring rods

REAGENTS

- hydrochloric acid, HCl (6 M, 200 mL)
- sodium hydroxide, NaOH (6 M, 200 mL)
- distilled water (300 mL)

PROCEDURE

NOTE:

- **Can perform on the visualizer, so students can see temperature values on the temperature probe.**
- **Please use small white tray provided to perform the experiment.**
- Place the temperature probe in a 300 mL beaker.
- Add 100 mL of distilled water and record the initial temperature.
- Add HCl (6 M, 100 mL), stir, and record the temperature change.
- Remove the probe and rinse it with distilled water.
- Place the probe in an empty 300 mL beaker.
- Add 100 mL of distilled water.
- Add NaOH (6 M, 100 mL) while stirring.
- Briefly rinse the probe again and place it in a third beaker.
- Add NaOH (6 M, 100 mL) and HCl (6 M, 100 mL).

RESULTS

The temperature rise for HCl/H_2O is ≈ 3˚C.
The temperature rise for $NaOH/H_2O$ is ≈ 1˚C.
The temperature rise for HCl/NaOH is ≈ 45˚C.

High Risk Demonstration:

- **Refer to HIRAC**
- **Set up in Red Tray**

DEMONSTRATION 4.10

AN ENDOTHERMIC REACTION: AMMONIUM THIOCYANATE AND BARIUM HYDROXIDE

Solid ammonium thiocyanate and solid barium hydroxide-8-water react endothermically and absorb heat from their surroundings.

EQUIPMENT

- a flat piece of wood about 20 x 20 x 1 cm thick
- 500 mL conical flask
- 2 x 100 mL beakers

REAGENTS

- ammonium thiocyanate, NH_4SCN (38 g)
- barium hydroxide-8-water, $Ba(OH)_2 \cdot 8H_2O$ (79 g)

PREPARATION

- Using the beakers weigh out ammonium thiocyanate (38 g) and barium hydroxide-8-water (79 g).
- Set up the empty, dry conical flask, the reagents and the piece of wood.

PROCEDURE

- Hold the piece of wood under a tap and allow a puddle of water to form in the middle of the slab.
- Combine the dry reagents in the flask and shake the mixture for about 15 seconds.
- Set the flask down over the puddle.

RESULTS

After about one minute, the endothermic reaction taking place in the flask will have drawn so much heat from its environment that the water freezes. Raise the flask to show that the piece of wood is now frozen to the bottom of the flask.

Note: It is important to show that tap water is used for wetting the wood in order to allay suspicions of trickery.

$$Ba(OH)_2 \cdot 8H_2O(s) + 2NH_4SCN(s) \zeta \square Ba(SCN)_2(s) + 2NH_3(g) + 10H_2O(l)$$

DEMONSTRATION 4.11

AN EXOTHERMIC REACTION: ALUMINIUM AND IRON(III) OXIDE

Aluminium powder and iron(III) oxide are mixed together and then ignited. Light and enough heat to melt iron are produced.

EQUIPMENT

- thick-walled ceramic or carbon crucible with hole in the bottom (about 9 cm high)
- large insulating mat
- bucket containing dry sand
- tongs
- 2 safety screens

REAGENTS

- aluminium powder, Al (5 g)
- iron(III) oxide, Fe_2O_3 (20 g)
- thermite mixture, Fe_3O_4/Fe/Al (150 g), (commercial mix)
- glycerine, $C_3H_5(OH)_3$ (5 mL).Do not exceed the 5mL quantity.
- potassium permanganate, $KMnO_4$ (10 g)

PREPARATION

- Place a piece of filter paper over the opening in the bottom of the crucible.

- Mix Al and Fe_2O_3 in a crucible with a nickel spoon. Do not grind.
- Pour 150 g of thermite mixture on the top of the paper.
- Pour Al/Fe_2O_3 mixture into the top of the thermite.
- Place the crucible in the crucible holder positioned above the bucket containing dry sand.
- Perform the demonstration inside the fume hood only.

PROCEDURE

- Ensure that there is no flammable substance within a 2 metre radius of the reaction vessel.
- Dim the lights.
- Make a depression in the Al/Fe_2O_3 mixture and pour 5 mL of glycerine into the depression.
- Pour 10 g of finely ground potassium permanganate on the top of the glycerine and quickly stand back.
- If the mixture fails to ignite, wait one minute then add 5 mL of glycerine and 10 g of ground $KMnO_4$.

CAUTION

Do not use a wet crucible. Seek instruction from lecture theatre staff. A CO_2 fire extinguisher must be handy. Do not use a water extinguisher as the addition of water to molten iron produces hydrogen which can lead to an explosion.

RESULTS

The reaction will last for several seconds and is accompanied by the emission of strong orange-yellow light, flying sparks and a hissing sound.

$3Fe_3O_4(s) + 8Al(s) \zeta 9Fe(s) + 4Al_2O_3(s)$

DEMONSTRATION 4.12

A SPONTANEOUS REACTION: WHITE PHOSPHORUS AND CARBON DISULFIDE

White phosphorus burns spontaneously in air and carbon disulfide burns explosively in air.

EQUIPMENT

- 1 L open mouth measuring cylinder
- 5 mL measuring cylinder
- 2 crystallising dishes, about 10 cm diameter
- piece of filter paper, 10 cm diameter
- pasteur pipette with teat
- 100 mL reagent bottle with large mouth
- knife or spatula
- tongs or tweezers
- stop cock grease or vaseline

REAGENTS

- white phosphorus, P (1 g)

CAUTION

White phosphorus must be kept under water at all times! It is spontaneously flammable in air. Combustion in air produces phosphorus pentoxide. Both white phosphorus and phosphorus pentoxide are very poisonous and can cause severe burns. Chronic effects can result from continued absorption of small amounts.

- carbon disulfide, CS_2 (5 mL)

CAUTION

Carbon disulfide is extremely flammable as well as toxic. The explosive range is 1-50% (V/V) in air.

PREPARATION Weigh out white phosphorus (1 g) following the procedure below.

Exposure of phosphorus to air should be very brief.

- Ensure that the fume-cupboard is free of flames and other sources of heat. Turn on ventilation.
- Place the container with phosphorus, the bottle with carbon disulfide, the small measuring cylinder and the empty reagent bottle into the fume-cupboard.
- Apply some stop cock grease to the lid of the reagent bottle and leave it beside the bottle.
- Pour some water into **both** crystallising dishes.
- Place one dish on the balance and tare it.
- Take the other to the fume-cupboard.

Ensure that during the following procedure all phosphorus is kept under water.

- Using tongs or tweezers, take a lump of phosphorus and transfer it quickly to the dish.
- Leaving the lump under water in the dish, cut off several small pieces.

- Now take the dish to the balance and using tweezers quickly transfer 1 gram's worth of the small pieces to the tared vessel.
- Take both dishes back to the fume-cupboard and return the unused phosphorus to the storage container immediately.
- Using the small measuring cylinder, transfer carbon disulfide (5 mL) to the reagent bottle.
- Using tweezers, add the weighed-out amount of phosphorus to the bottle. Swirl gently to ensure dissolution.
- Seal the bottle securely with the greased lid.
- Provide the 1 L measuring cylinder, filter paper and pasteur pipette.

PROCEDURE

- Turn on ventilation of the fume cupboard.
- Rest a piece of filter paper over the mouth of the measuring cylinder.
- Using the pasteur pipette, transfer about 1 mL of solution from the reagent bottle to the centre of the filter paper.
- Dim the lights.

RESULTS

The carbon disulfide will evaporate within one or two minutes of being placed on the filter paper. The vapour, being quite dense, will move downwards into the measuring cylinder where an explosive mixture with air will form.

$P_4(s) + 5 \quad O_2(g) \zeta P_4O_{10}(s)$

Once the phosphorus is dry, it will ignite spontaneously and cause the filter paper to burst into flames. Blue and yellow flames will appear in the top portion of the cylinder. The carbon disulfide further down will explode with a hooting sound. The burning filter paper will become airborne. A large amount of phosphorus pentoxide will evolve which must not be allowed to escape from the fumehood.

Note: The time taken for complete evaporation varies with room temperature and the amount of solution delivered to the paper.

DISPOSAL

The cooled, charred filter paper should be discarded in a waste container. The cylinders can be cleaned by scrubbing with soap and water. Any remaining white phosphorus in carbon disulfide should be placed in a flat pan in a ventilated fume cupboard away from other combustible materials and allowed to evaporate and burn.

High Risk Demonstration:

- **Refer to HIRAC**
- **Set up in Red Tray**

DEMONSTRATION 4.13

A SPONTANEOUS REACTION: COMBUSTION OF ACETYLENE IN BLEACH

Chlorine gas is generated when hydrochloric acid and bleach are mixed. When a small amount of calcium carbide is added to the gas, a spontaneous reaction occurs in which a flame is produced.

EQUIPMENT

- Gas jar
- watch glass

REAGENTS

- household chlorine bleach containing hypochlorite, ClO^- (5 mL)
- hydrochloric acid, HCl (5 M) (4mL)
- calcium carbide, CaC_2 (Make sure not to use the top layer from the chemical bottle as it might have already been oxidised. Scrap away a bit of the top layer and use the solid from the bottom)

PROCEDURE

- Generate chlorine gas by placing 5mL of Bleach in the gas jar and add 4mL of 5M HCL. You can also prepare Bleach solution by dissolving 1 Bleach tablet in 100mL of water.

- Cover the beaker and leave for approximately thirty seconds**.**
- Remove the watch glass and add a lump of calcium carbide to the beaker to generate the acetylene .
- Perform this demonstration in a fumehood.

RESULTS The liberated acetylene reacts spontaneously with the chlorine gas to give a flame.

$ClO^-(aq) + Cl^-(aq) + 2H^+(aq) \zeta Cl_2(g) + H_2O(l)$

$CaC_2(s) + 2H_2O(l) \zeta C_2H_2(g) + Ca(OH)_2(s)$

$C_2H_2(g) + Cl_2(g) \zeta ClCH=CHCl\ (g)$