

DEMONSTRATION 6.1

ELECTRICITY BY A CHEMICAL REACTION

A strip of copper and a strip of magnesium are placed in sulfuric acid. The voltage produced by the electrochemical cell is sufficient to fire a flash bulb.

EQUIPMENT

- 250 mL beaker
- low voltage light
- electrical socket
- test tube
- battery alligator clip

REAGENTS



- Hydrochloric acid, HCl (1 M, 200 mL)
- 30 cm length of copper wire
- 30 cm strip of magnesium ribbon

PREPARATION

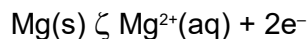
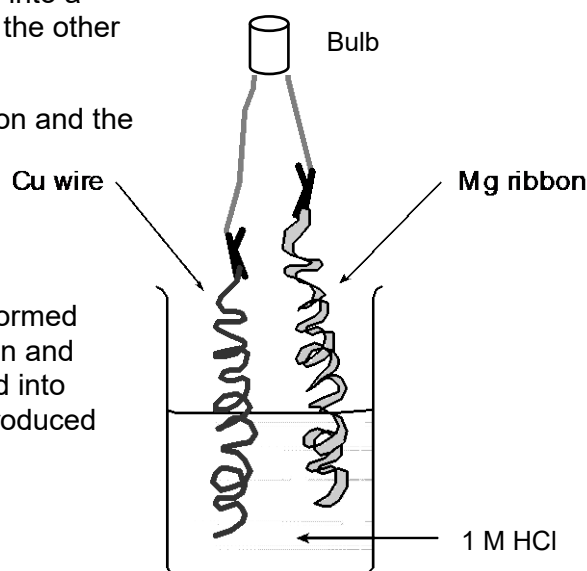
- Attach the clips to the small light.
- Wind the magnesium ribbon into a spiral and connect to an alligator clip.
- Wind the copper wire into a spiral and attach it to the other alligator clip.

PROCEDURE

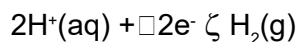
Lower the magnesium ribbon and the copper wire simultaneously into the beaker containing the hydrochloric acid.

RESULTS

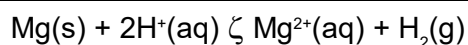
An electrochemical cell is formed when the magnesium ribbon and the copper wire are lowered into the beaker. The voltage produced by the chemical reaction is sufficient to light the bulb.



$$E^{\circ} = +2.36 \text{ V}$$



$$E^{\circ} = 0.00\text{V}$$



$$E^{\circ}_{\text{cell}} = +2.36\text{V}$$

DEMONSTRATION 6.2

THE LEMON BATTERY

A strip of copper and a strip of zinc are embedded in a lemon and a small voltage is generated.

EQUIPMENT

- voltmeter
- 2 alligator clips
- 1 strip of copper (clean)
- 1 strip of zinc (clean)
- 1 lemon

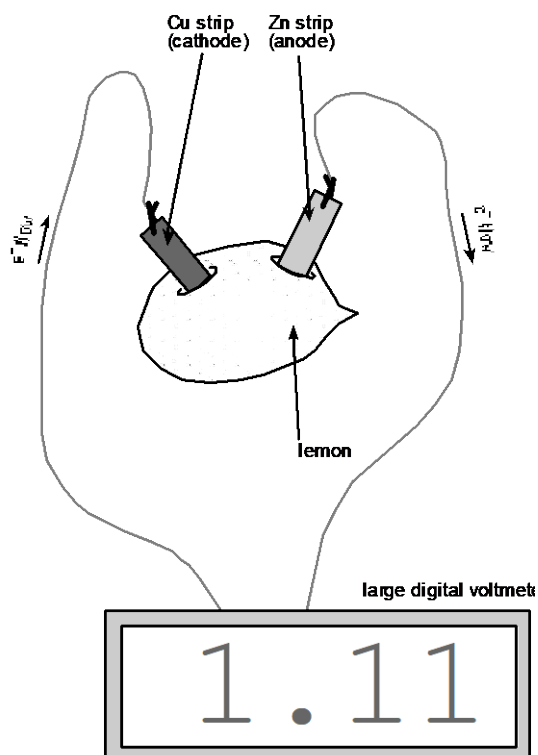
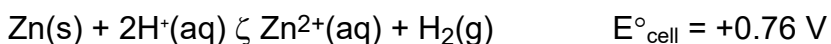
PROCEDURE

- Insert the zinc and copper strips into the lemon and attach alligator clips onto the strips.
- Connect wires onto voltmeter.
- Observe the voltage.

RESULTS

A cell voltage of over a volt is observed.

The cell reaction is:



DEMONSTRATION 6.3

ZINC IN COPPER SULFATE SOLUTION

A strip of zinc is placed in a copper sulfate solution and left for a day. The solution becomes colourless and contains a sediment of copper metal.

EQUIPMENT • 500 mL beaker

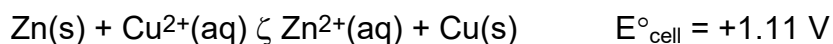
REAGENTS • strip of zinc (about 20 cm long)
• copper(II) sulfate-5-water, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (100 g)

PREPARATION • Dissolve 125 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in water and make up to 400 mL.

PROCEDURE Place the strip of zinc into the solution and allow to stand for one day.

RESULTS Much of the zinc strip disappears. The solution turns colourless and a sediment of metallic copper forms on the bottom of the vessel.

The reactions are:



DEMONSTRATION 6.4

COPPER IN SILVER NITRATE SOLUTION: “THE SILVER TREE”

A spiral of copper metal is placed in a solution of silver nitrate. Overnight, the copper dissolves, silver is precipitated and the solution turns blue.

EQUIPMENT

- 500 mL beaker

REAGENTS

- 1 spiral of copper wire
- silver nitrate, AgNO_3 (0.1 M, 500 mL)

PREPARATION

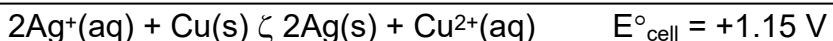
- Dissolve 8.5 g AgNO_3 in 500 mL of water.
- Place the 500 mL of silver nitrate solution into the beaker.

PROCEDURE

- Place the copper strip into the silver nitrate solution.
- Allow to stand for one day.

RESULTS Elemental silver is deposited on the surface of the copper as a spongy mass of small brilliant needles. The effect produced is that of a “silver tree.” The solution becomes pale blue.

The reaction that occurs is :



DEMONSTRATION 6.5

IRON(II) SULFATE AND POTASSIUM PERMANGANATE

Green iron(II) sulfate solution is oxidised by a purple potassium permanganate solution, to give a colourless solution of iron(III) and manganese(II).

EQUIPMENT

- 100 mL measuring cylinder
- 2 L conical flask
- long glass rod
- light box

REAGENTS



- potassium permanganate, KMnO_4 (a few crystals)
- iron(II) ammonium sulfate-6-water, $(\text{NH}_4)_2\text{Fe}(\text{SO}_4)_2 \cdot 6\text{H}_2\text{O}$ or Iron (II) sulfate (50 g)
- sulfuric acid, H_2SO_4 (2 M, 100 mL)
- distilled water

PREPARATION

- Dissolve 50 g iron (II) ammonium sulfate-6-water or Iron (II) sulfate in 150 mL of 2 M sulfuric acid.
- Set up the light box.
- Fill the conical flask with water and add crystals of potassium permanganate, sufficient to produce a solution which is strongly coloured without being opaque.
- Provide measuring cylinder and stirring rod.

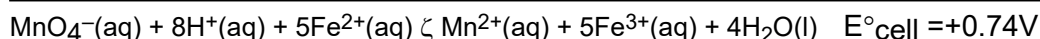
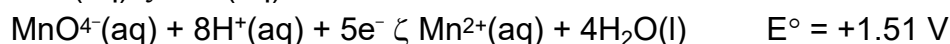
PROCEDURE

- Add 150 mL of the iron(II) sulfate solution to the potassium permanganate solution.
- Stir.

RESULTS

Permanganate is reduced to Mn(II) and Fe(II) is oxidised to Fe(III) .

The reactions are:



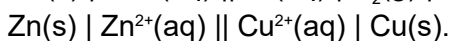
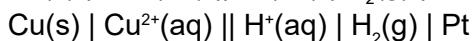
High Risk Demonstration:

- Refer to HIRAC
- Set up in Red Tray

DEMONSTRATION 6.6

ELECTROCHEMICAL CELLS

The following electrochemical cells are examined:



EQUIPMENT



- hydrogen half cell
- voltmeter
- leads with alligator clips
- large digital display
- 3 x 250 mL beakers
- 2 salt bridges (see below) in storage vessel
- retort stand
- 2 boss heads and clamps
- tweezers or tongs and tissues
- small beaker for used salt bridges
- rubber tubing to fit regulator and hydrogen cell

REAGENTS



- hydrogen gas cylinder with appropriate regulator
- hydrochloric acid, HCl (1 M, 250 mL)
- copper(II) sulfate-5-water, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (1M)
- zinc sulfate-6-water, $\text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$ (1M)
- 20 cm strip of copper sheet
- 20 cm strip of zinc sheet

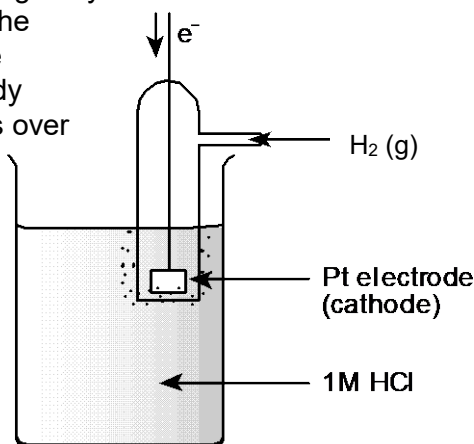
For the salt bridge: -

- potassium nitrate, KNO_3 (5 g)
- agar (1 g)

PREPARATION Constructing the salt bridge

- Prepare the salt bridges by making a mixture of: 50 mL distilled water, 5 g potassium nitrate, 1 g agar
- Place this mixture on a steam bath until dissolved (usually about 20 minutes).
- Make U-tubes by bending glass tubing of about 5 mm diameter to form a U-shape about 4 cm high.
- Using a small plastic funnel, fill these tubes with the hot agar solution.
- Leave the tubes to stand overnight. These salt-bridges can be kept indefinitely in a stoppered bottle containing 1 M potassium nitrate solution.
- Prepare 250 mL of 1 M copper sulfate by dissolving 62.5 g $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ in water and making up to 250 mL.
- Similarly, prepare 250 mL of 1 M zinc sulfate by dissolving 67.5 g $\text{ZnSO}_4 \cdot 6\text{H}_2\text{O}$ in water and making up to 250 mL.
- Set up the Voltmeter.
- Set up a **standard hydrogen half-cell** by filling one of the 250 mL beakers with hydrochloric acid solution and immersing the glass apparatus containing the platinum electrode in it.

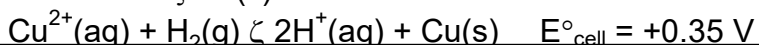
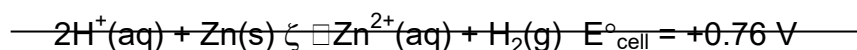
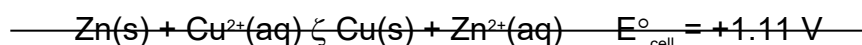
- Set the beaker on the foot of the retort stand and, using the clamp, secure the cell. Set up the hydrogen cylinder.
- Connect cell and cylinder with the tubing. Adjust the valves of the regulator so that a gentle, steady stream of hydrogen gas passes over the electrode.
- Turn off the gas flow at the main valve.
- Prepare a **copper half-cell** by filling a 250 mL beaker with the copper solution and placing the copper strip in it.
- Prepare a **zinc half-cell** by filling a 250 mL beaker with the zinc solution and placing the zinc strip in it.
- Line up the three half-cells with the hydrogen cell in the middle.
- Supply the salt bridges in their storage vessel as well as the beaker for their disposal.
- After the demonstration, the contaminated agar may be removed from the used bridges by heating them in water.

**PROCEDURE**

- Use salt bridges to connect the half-cells.
- Turn on the Voltmeter and attach the terminals across the half-cell electrodes
- Note the readings of each combination.

RESULTS

E°_{cell} for the three cells should be close to the calculated values shown below.

copper and hydrogen half cells:**zinc and hydrogen half cells:****copper and zinc half cells:**

High Risk Demonstration: Refer to HIRAC

DEMONSTRATION 6.7

ACTIVITY SERIES OF METALS

The activity of five metals is compared.

EQUIPMENT

- 1 large petri dish
- 1 piece or strip of magnesium, zinc, iron, tin and copper metal, each of similar size
- overhead projector transparency

REAGENTS



- hydrochloric acid, HCl (5 M, 100 mL)
- Mg, Zn, Fe, Sn and Cu metals

PROCEDURE

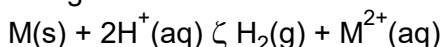
- Trace the circumference of the petri dishes onto the overhead projector transparency and label 5 inside areas with Mg, Zn, Fe, Sn and Cu.
- Place the transparency on the projector underneath the petri dish.
- Fill the petri dish with acid and immerse the piece of each metal over its label.

RESULTS

The order of activity of the metals is assessed from how vigorously they react:



The general reaction is:



High Risk Demonstration:

- Refer to HIRAC
- Set up in Red Tray

DEMONSTRATION 6.8

CONCENTRATION CELL

Two identical copper half cells are constructed. On the addition of sodium sulfide solution to one of them, a precipitate forms in the beaker and a voltage is detected.

EQUIPMENT

- U-tube salt bridge as in Demonstration 6.6
- 2 x 600 mL beakers
- 50 mL burette with stand
- voltmeter
- alligator leads
- plastic funnel.
- large digital display



REAGENTS

- copper(II) sulfate-5-water, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (25 g)
- sodium sulfide-9-water, $\text{Na}_2\text{S} \cdot 9\text{H}_2\text{O}$ (24 g)
- copper metal (2 strips)

PREPARATION

- Dissolve copper(II) sulfate-5-water (25 g) in water (1 L).
- Dissolve sodium sulfide-9-water (24 g) in water (100 mL).
- Pour 400 mL of copper sulfate solution into each beaker.
- Since sodium sulphide has a pungent smell, fill the burette with 50 mL sodium sulfide solution just before the demonstration. Leave a plastic funnel on the top of the burette.

PROCEDURE

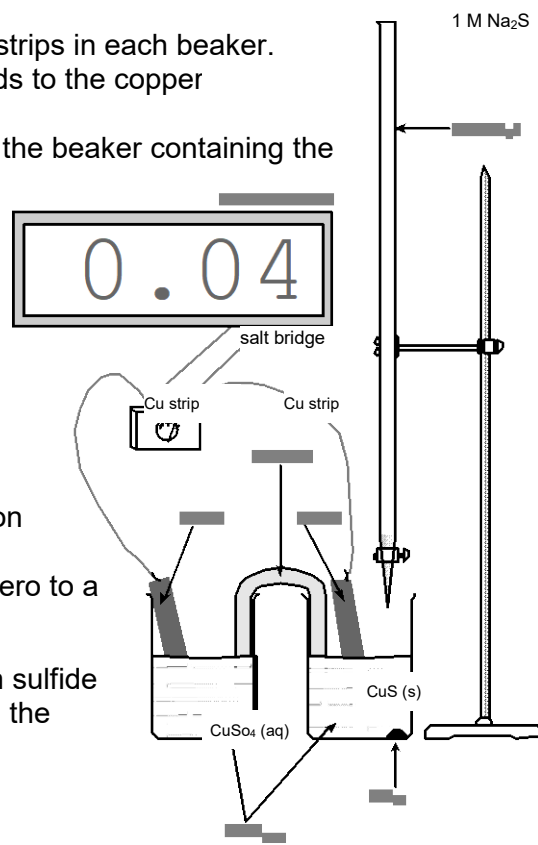
- Place the beakers of copper sulfate solution side by side with the salt bridge connecting them.
- Place one of the copper strips in each beaker.
- Connect the alligator leads to the copper and the voltmeter.
- Position the burette over the beaker containing the copper strip to which the negative lead is attached.
- Add a few drops of sodium sulfide solution to the beaker.
- Progressively run in the remaining solution.

RESULTS

Initially, a voltage close to zero should be observed. On addition of sodium sulfide solution, the voltage should increase from zero to a maximum of 0.6 volts.

DISPOSAL

The copper sulfate and sodium sulfide solutions may be flushed down the



Chapter 6: Redox

sink with water. The copper sulfate solution to which sodium sulfide has been added should be filtered to remove the copper sulfide precipitate. The filtrate may be flushed down the sink and the residue discarded with solid wastes.

DEMONSTRATION 6.9

A COMPARISON OF SALT BRIDGES

A galvanic cell is set up and three salt bridges are compared: a standard agar salt bridge; a sodium chloride bridge; and the human body acting as a salt bridge.

EQUIPMENT

- voltmeter
- 2 x 100 mL beakers
- salt bridge as used in Demonstration 6.6
- filter paper
- one strip of Zn metal
- one strip of Cu metal.

REAGENTS

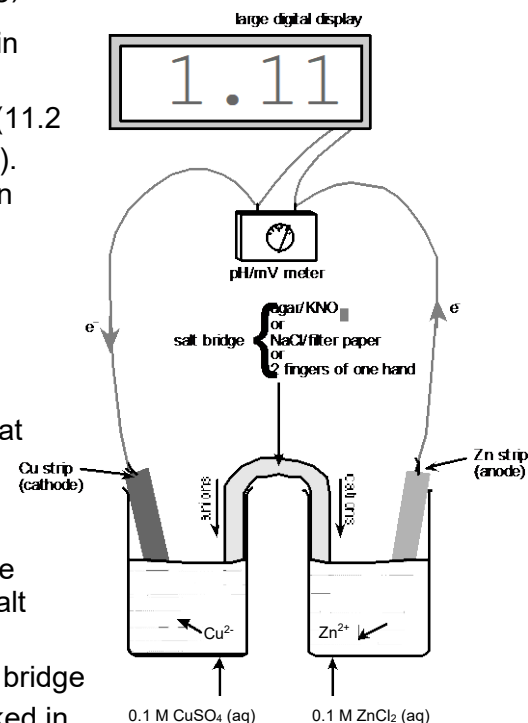
- zinc chloride, ZnCl_2 (6.1 g), (0.1M)
- copper(II) sulfate-5-water, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (11.2 g), (0.1M)
- sodium chloride, NaCl (0.2 g)

PREPARATION

- Dissolve solid ZnCl_2 (6.1 g) in distilled water (450 mL)
- Dissolve solid $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (11.2 g) in distilled water (450 mL).
- Dissolve solid NaCl (0.2 g) in distilled water (30 mL)

PROCEDURE

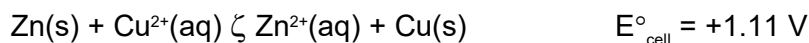
- Place the ZnCl_2 and CuSO_4 solutions into individual beakers.
- Set up the galvanic cell as shown in the figure. Note that the Zn strip is connected to the negative terminal of the voltmeter.
- Measure the voltage with the conventional (agar/ KNO_3) salt bridge.
- Replace the agar/ KNO_3 salt bridge with filter paper freshly soaked in the NaCl solution and measure the voltage.
- Finally, replace the filter paper with two fingers of the same hand and measure the voltage again.



RESULTS

The voltages using the three salt bridges decrease in the order: agar/ KNO_3 > filter paper/ NaCl > human body.

The voltage for the KNO_3 bridge will be near the calculated E°_{cell} below.



DEMONSTRATION 6.10

ELECTROLYSIS

A voltage is applied to a solution of water containing universal indicator. Distinct gases are evolved at the cathode and anode and the reactions taking place are indicated by colour changes of the indicator.

EQUIPMENT

- electrolysis cell
- retort stand and clamp
- 500 mL beaker
- stop cock grease
- 12 volt DC power supply
- leads with alligator clips
- large universal indicator/pH chart

REAGENTS

- Sodium sulphate solution (0.5 M, 200 mL) (14.2g)
- universal indicator

PREPARATION



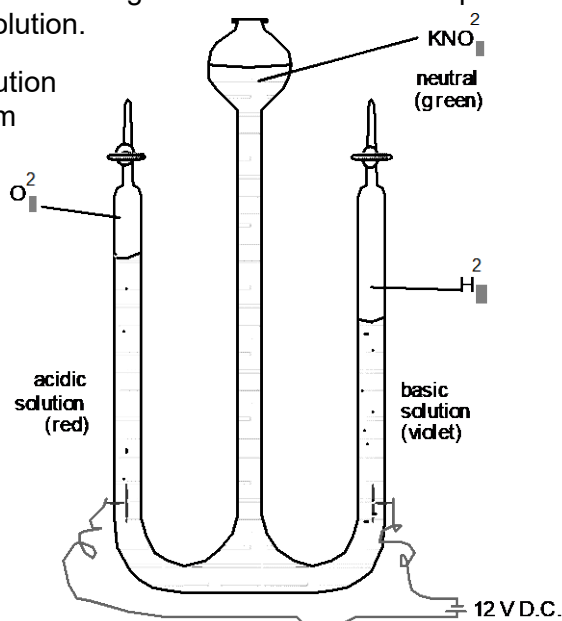
- Add universal indicator to 200 mL of the 0.5M sodium sulfate solution prepared by dissolving 14.2g of the solid in 200mL of deionised water.
- Using the retort stand, set up the electrolysis apparatus and connect it to the power supply.
- Do not switch on.
- Ensure that the stop cocks are well greased but leave them open.
- Provide the beaker with solution.

PROCEDURE

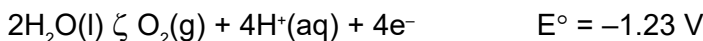
- Fill the apparatus with solution until the level is about 2 cm below the stop cocks.
- Close the cocks.
- Apply 12 volt DC across the electrodes of the apparatus.

RESULTS

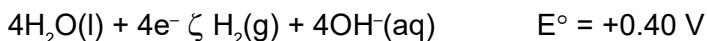
The two electrodes will evolve hydrogen and oxygen respectively, depending on the sign of the charge on the electrode.



At the anode, water is oxidised:



At the cathode, water is reduced:



The equations show that twice the amount of hydrogen will be produced than oxygen, and this should be observable from the water levels in the tubes.

$\text{H}^+(\text{aq})$ is produced at the anode and the universal indicator turns red. $\text{OH}^-(\text{aq})$ is produced at the cathode and the universal indicator turns violet.

DEMONSTRATION 6.11

COPPER TO “SILVER” TO “GOLD”

Copper disks are plated with zinc or tin to give “silver”. Then the zinc and copper are heated to give a brass alloy, “gold”. If copper and tin are heated, the alloy is bronze.

EQUIPMENT

- 150 mL beaker
- 250 mL beaker
- Bunsen burner
- tripod
- wire gauze
- tongs
- paper towel
- 3 copper disks, 5 cm in diameter
- steel wool

REAGENTS

- granular zinc (25 g) (granular tin may also be used).
- sodium hydroxide, NaOH (3 M, 50 mL)

PREPARATION



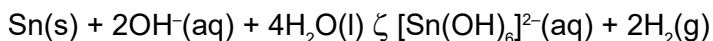
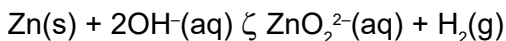
- Polish the copper disks using the steel wool until they are shiny.
- Place the sodium hydroxide solution in the 150 mL beaker on the tripod over the Bunsen burner.
- Add the zinc granules and bring to the boil.

PROCEDURE

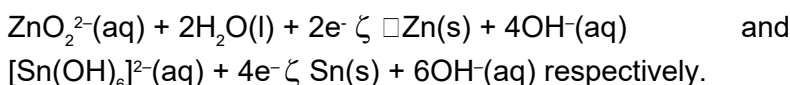
- When the sodium hydroxide solution is boiling, use the tongs to place two of the prepared copper disks on top of the zinc granules, ensuring that they are covered by solution.
- When the disks are silvered, remove them with the tongs and place them in the 250 mL beaker containing water.
- Once cool, dry them, and take one coin in the tongs and heat it in the blue part of the Bunsen flame.
- Heat it briefly and evenly until it changes to a golden colour.
- Remove it from the flame, cool and dry.
- Place the three disks side by side for comparison.

RESULTS

If zinc is used, the “silver” coating is zinc, and the “gold” coating is brass. If tin is used, the “silver” coating is tin, and the “gold” coating bronze. In strongly alkaline solution, the zinc or tin dissolves to form the zincate or stannate ion respectively.



Bubbles of hydrogen are seen in the solution before it is heated; heating speeds the reaction. The electrochemistry of the deposition is not known, although it is thought to be a concentration cell based upon the reaction



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

DEMONSTRATION 6.12

DRY CELL

A dry cell is constructed based on the same reaction as commercial alkaline batteries.

EQUIPMENT

- 1 slice of packing foam
- alligator clips
- voltmeter
- 1 large beaker
- pieces of string, disposable gloves, carbon rods

REAGENTS



- powdered manganese dioxide, MnO_2 (3-4 g)
- ammonium chloride, NH_4Cl (4 M, 100 mL)
- zinc foil (1 piece)

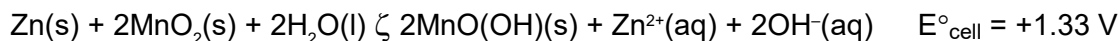
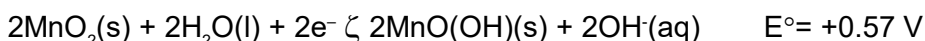
PREPARATION Prepare the ammonium chloride solution by dissolving ammonium chloride (21.4 g) in water (100 mL).

PROCEDURE

- Cover the surface of the demonstration bench.
- Pour the ammonium chloride solution into the large beaker and moisten the packing foam in the bottom of the beaker.
- Squeeze the foam so that it is damp but not dripping; then sprinkle over the manganese dioxide.
- Roll the sprinkled foam around the carbon rod.
- Next wrap the foam in the zinc foil, ensuring that the zinc does not touch the carbon rod. (Tie the assembly together with string.)
- Connect one alligator clip from the Voltmeter to the graphite rod, and the other to the zinc foil.

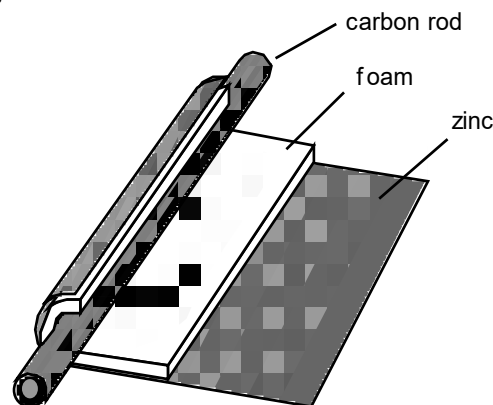
RESULTS

A voltage of about 1.3 volts should be observed.



The zinc foil may be rinsed, air dried and reused until it is too corroded to

bend and to be used again.



DEMONSTRATION 6.13

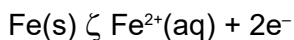
RUSTING AND CATHODIC PROTECTION

An iron nail is placed in an agar solution and within an hour the areas around the head and tip of the nail have turned blue, while the area around the body of the nail has turned pink. Another nail wrapped with a magnesium strip is placed in the agar but shows no colour change to blue.

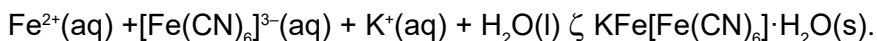
- EQUIPMENT**
- 2 iron nails
 - 2 petri dishes
 - 1 strip of magnesium
- REAGENTS**
- potassium hexacyanoferrate(III), $K_3[Fe(CN)_6]$ (1.65 g) , (0.1M)
 - phenolphthalein indicator (2 mL)
 - potassium nitrate, KNO_3 (5 g)
 - agar (1 g)
- PROCEDURE**
- Prepare a 0.1 M potassium hexacyanoferrate(III) solution by dissolving 1.65 g in 10mL.
 - Prepare the agar gel by making a mixture of 50 mL distilled water, 5 g potassium nitrate, 1 g agar, 10 mL of 0.1 M potassium hexacyanoferrate(III) and 10 drops phenolphthalein indicator.
 - Place this mixture on a steam bath until the agar dissolves (usually about 20 minutes).
 - Place some agar gel into two petri dishes.
 - In one dish place an iron nail, into the other dish place a nail with magnesium strip wrapped around it.

RESULTS

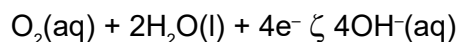
The unprotected nail, acting as both anode and cathode, will show regions of blue and pink coloration. Iron is oxidised to Fe^{2+} , which then reacts with potassium hexacyanoferrate(III) ion to give the dark blue precipitate known as *Turnbull's blue*. These blue regions appear around the head and tip of the nail. Oxidation occurs at these areas because the strained metal is more anodic (more active) than the body of the nail.



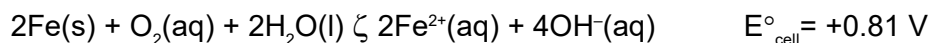
The Fe^{2+} reacts with $K_3[Fe(CN)_6]$ to produce the blue precipitate



The electrons released at the two ends of the nail migrate to the body of the nail where they are used to reduce dissolved oxygen in the gel to $OH^{-}(aq)$. The increased concentration of $OH^{-}(aq)$ causes the phenolphthalein to turn magenta.



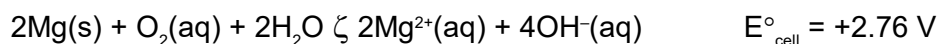
The overall redox reaction is



The nail protected with magnesium, on which the magnesium functions as the cathode, shows no blue or black regions indicating that no corrosion of the iron nail has taken place. Here magnesium is oxidised in preference to the iron. The electrons released in the oxidation of the magnesium are again used to reduce oxygen to hydroxide which turns the phenolphthalein magenta.



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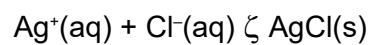
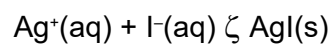


DEMONSTRATION 6.14

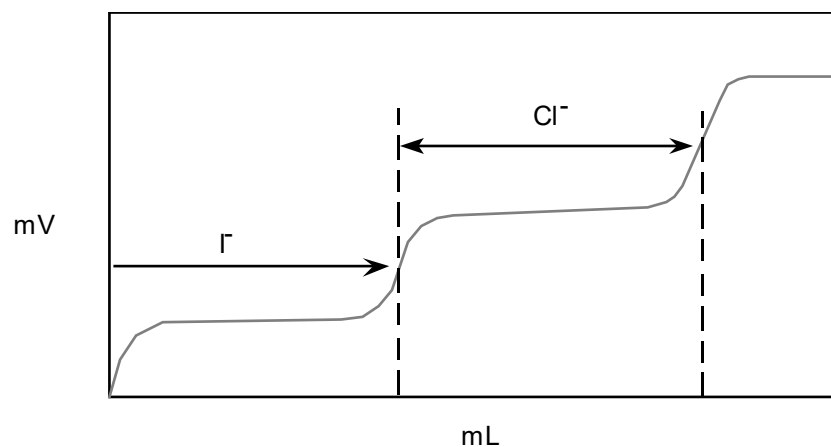
TITRATION OF HALOGEN IONS WITH SILVER

As the titration of halide ions with silver ions is performed a graph is produced showing the potential changes of the solution.

EQUIPMENT	<ul style="list-style-type: none"> • indicator electrode: silver, solid state, P4011 • reference electrode: mercury/mercurous sulfate • stand • Voltmeter with banana-plug adaptor • large digital display • 50 mL burette and stand • 3 x 500 mL volumetric flasks • 4 x 100 mL measuring cylinders • 250 mL beaker • wash bottle with distilled water • magnetic stirrer • paper tissues • transparency with graph grid • 2 pens for over-head transparencies (fine point, 2 colours)
REAGENTS	<ul style="list-style-type: none"> • potassium iodide, KI (0.1 M, 500 mL) • sodium chloride, NaCl (0.1 M, 500 mL) • silver nitrate, AgNO₃ (0.1 M, 500 mL) • nitric acid, HNO₃ (0.1 M, 500 mL) • distilled water
PREPARATION	<ul style="list-style-type: none"> • To separate 500 mL volumetric flasks add potassium iodide (8.3 g), sodium chloride (2 g), silver nitrate (8.5 g) to give 0.1 M solutions of these reagents. • Setup the voltmeter. • Place the transparency and pens on the over-head projector. Connect the projector to the mains. • Set up the solutions in their labelled flasks and place a labelled measuring cylinder with each. • Fill the burette with silver nitrate solution and set it up over the stirrer. • Position the electrodes so that they will reach into the beaker without interfering with each other, the burette or the spin bar. • Provide tissues and wash bottle.
PROCEDURE	<ul style="list-style-type: none"> • Dim the lecture theatre lights. • To the 250 mL beaker add KCl (10 mL), KI (20 mL) and HNO₃ (20 mL). • Place the beaker on the stirrer and allow to mix. • Add silver nitrate solution from the burette in convenient units - say 1 mL. • After each addition allow sufficient time for mixing to complete and the mV reading to stabilise. • Plot the mV against mL on the over-head transparency.

RESULTS

The resultant curve should have the following shape:

**High Risk Demonstration:**

- Refer to HIRAC
- Set up in Red Tray

DEMONSTRATION 6.15

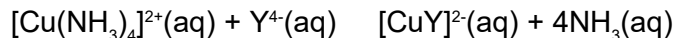
ION-SELECTIVE TITRATION

- EQUIPMENT**
- indicator electrode: ion-specific electrode: Orion Cupric Selective, Cat.No.24-29A
 - reference electrode: mercury/mercurous sulfate
 - electrode stand
 - voltmeter with banana-plug adaptor
 - large digital display
 - double adaptor
 - magnetic stirrer
 - spin bar
 - 50 mL burette
 - retort stand
 - 100 mL measuring cylinder
 - 250 mL beaker
 - 2 x 250 mL volumetric flasks
 - 2 x 250 mL reagent bottles
 - wash bottle with distilled water
 - paper tissues
 - transparency with graph grid
 - 2 pens for over-head transparencies (fine point, 2 colours)
- REAGENTS**
- copper(II) sulfate-5-water, $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ (0.62 g)
 - sodium ethylenediaminetetraacetic acid-2-water, $\text{Na}_2\text{H}_2\text{EDTA} \cdot 2\text{H}_2\text{O}$ (0.93 g)
 - ammonia, NH_3 (15 M, 10 mL)
- PREPARATION**
- Prepare a 0.01 M aqueous solution of copper(II) sulfate by dissolving 0.62 g in a 250 mL volumetric flask.
 - Dilute 50 mL of this with 200 mL of distilled water.
 - Add 10 mL of concentrated ammonia solution.
 - Place this solution into a stoppered reagent bottle.
 - Prepare 250 mL of a 0.01 M solution of EDTA by dissolving 0.93 g of the EDTA salt in a 250 mL volumetric flask.
 - Setup the voltmeter
 - Place the graph transparency and pens on the over-head projector.
 - Provide the solutions, measuring cylinder, wash bottle and tissues.
 - Fill the burette with EDTA solution and set it up over the beaker.
 - Place the electrodes so that they will reach into the beaker without interfering with each other, the burette or the spin bar.
- PROCEDURE**
- Dim the room. Switch on instruments and appliances.
 - Place some copper(II) sulfate solution into the beaker and add the spin bar. Switch on the stirrer.
 - Add EDTA solution from the burette in convenient units - say 1 mL.
 - After each addition, allow some time for mixing to complete and the reading to stabilise.
 - Plot mV against mL on the overhead transparency.

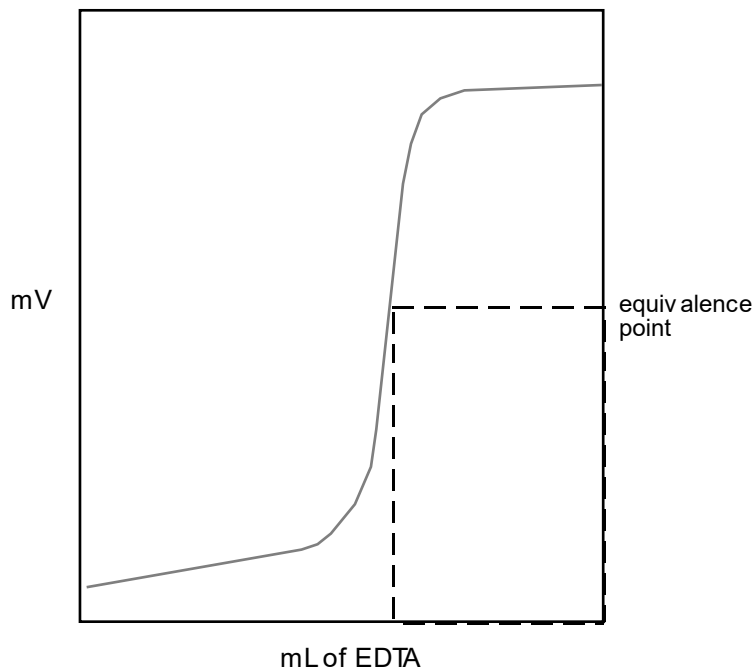
RESULTS

The final potential should be -700 mV.

Note: The presence of ammonia has a two-fold purpose: it fixes the pH of the system to about 10, and secondly it keeps Cu^{2+} in solution by forming ammine complexes. The complexes $[\text{Cu}(\text{NH}_3)(\text{H}_2\text{O})_3]^{2+}$, $[\text{Cu}(\text{NH}_3)_2(\text{H}_2\text{O})_2]^{2+}$, $[\text{Cu}(\text{NH}_3)_3(\text{H}_2\text{O})]^{2+}$, and $[\text{Cu}(\text{NH}_3)_4]^{2+}$ are all present in varying concentrations at pH 10. EDTA is a stronger chelating agent than ammonia and it will tend to displace the ammine ligands.



The resultant graph should have the following shape:



High Risk Demonstration:

- Refer to HIRAC
- Set up in Red Tray

DEMONSTRATION 6.16

COLOURFUL REDOX REACTIONS

This demonstration is popularly known as the 'Magic jug' and demonstrates the various oxidation–reduction reactions of iodide and iodate and colour changes of three indicators.

EQUIPMENT

- 1 L beaker
- 5 x 250 mL beakers
- light box

REAGENTS



- sulfuric acid, H_2SO_4 (2 M, 11 mL)
- sodium sulfite-7-water, $\text{Na}_2\text{SO}_3 \cdot 7\text{H}_2\text{O}$ (12.6 g)
- sodium hydroxide, NaOH (4 g)
- potassium iodide, KI (2 g)
- potassium iodate, KIO_3 (3 g)
- phenolphthalein indicator
- o-cresolphthalein indicator
- deionised water
- Vitex (starch indicator)

PREPARATION

- Dissolve 12.6 g sodium sulfite-7-water in 100 mL of water.
- Make up in advance, label the beakers “1” through to “5” and place the specified amounts of the respective solutions into them:
 1. phenolphthalein in ethanol, 4% 1 mL
 2. o-cresolphthalein in ethanol, 4% 1 mL
 3. sulfuric acid, 2 M 4 mL
 4. sulfuric acid, 2 M with vitex 4 mL
 5. sodium sulfite, 1 M (fresh) 5 mL
- **Make up fresh –Solution A:** Dissolve 2 g of sodium hydroxide, 1 g of potassium iodide and 1.5 g of potassium iodate in about 30 mL of water.
- Place this solution in a 50mL volumetric flask and make up to the mark.
- Place 2 mL of this solution into the jug and make up to 1 L.
- Try out the demonstration and adjust the amount of Vitex (1 spatula will work)
- Line up the beakers on the light box and provide the 1 L beaker.

PROCEDURE

- Pour about 200 mL of the contents of the jug into each beaker.
- Note colour-changes.
- Then return all solutions to the 1 L beaker.

RESULTS

Seen from a distance, the 250 mL beakers will appear empty.

After addition of the clear and colourless solution from the 1 L beaker, the beakers will appear to contain the following "drinks":

1. "claret" – due to the phenolphthalein indicator turning pink in the presence of base.
2. "port" – due to the *o*-cresolphthalein indicator in the presence of base (the *o*-cresolphthalein turns clear at a pH of 8.4).
3. "apple juice" – due to the acidification of iodide and iodate resulting in the production of iodine (triiodide).
4. "ink" – due to the iodine reacting with starch to form a complex (this solution is rather thin).
5. "water" – sodium sulfite has no effect.

When all solutions are again combined in the jug, this will appear to contain once more just "water". Iodide and iodate are regenerated by the reaction with sulfite and the solution becomes acidic (both acid/base indicators are colourless in acidic conditions).

DEMONSTRATION 6.17

ELECTROCHEMICAL WRITING

Electrochemical writing uses colour changes caused by the products of electrochemical reactions.

EQUIPMENT

- sheet of aluminium foil
- tape
- sheet of glass or wood (15 x 15 cm)
- 2 sheets of filter paper
- 1 sheet of typing paper
- copper wire (18 gauge or thicker)
- glass tubing
- 12 volt DC power source
- alligator clip

REAGENTS



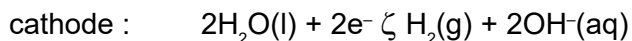
- potassium iodide, KI (1.6 g)
- starch solution (1% wt/wt, 5 mL)
- water (20 mL)
- phenolphthalein indicator (5 mL)
- dilute sodium thiosulfate, Na₂S₂O₃ (a few drops)

PROCEDURE

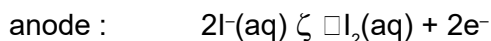
- Tape or cement the aluminium foil to the glass or wood sheet.
- Tape a sandwich consisting of filter paper, typing paper and another sheet of filter paper at one edge only onto the aluminium.
- Prepare a stylus from a length of copper wire looped at the end and passed through a length of glass tubing.
- Prepare a fresh solution consisting of potassium iodide (1.6 g), water (20 mL), starch solution (5 mL), and phenolphthalein indicator (5 mL). (If the solution darkens after standing for several days, it can be decolorised by adding drops of dilute sodium thiosulfate.)
- Soak the 3 layers of paper with the KI/starch/phenolphthalein solution.
- Connect the stylus and foil to a 12 V DC power supply, and write on the paper with the stylus.

RESULTS

When the stylus is the cathode, a pink colour appears from the reaction of OH⁻(aq) with phenolphthalein:



When the polarity is reversed and the stylus is the anode, a black (or very dark blue) colour appears from the reaction of I₂ with starch :



When the filter paper and typing paper are turned over, the writing appears in the opposite colour on the bottom sheet of filter paper.