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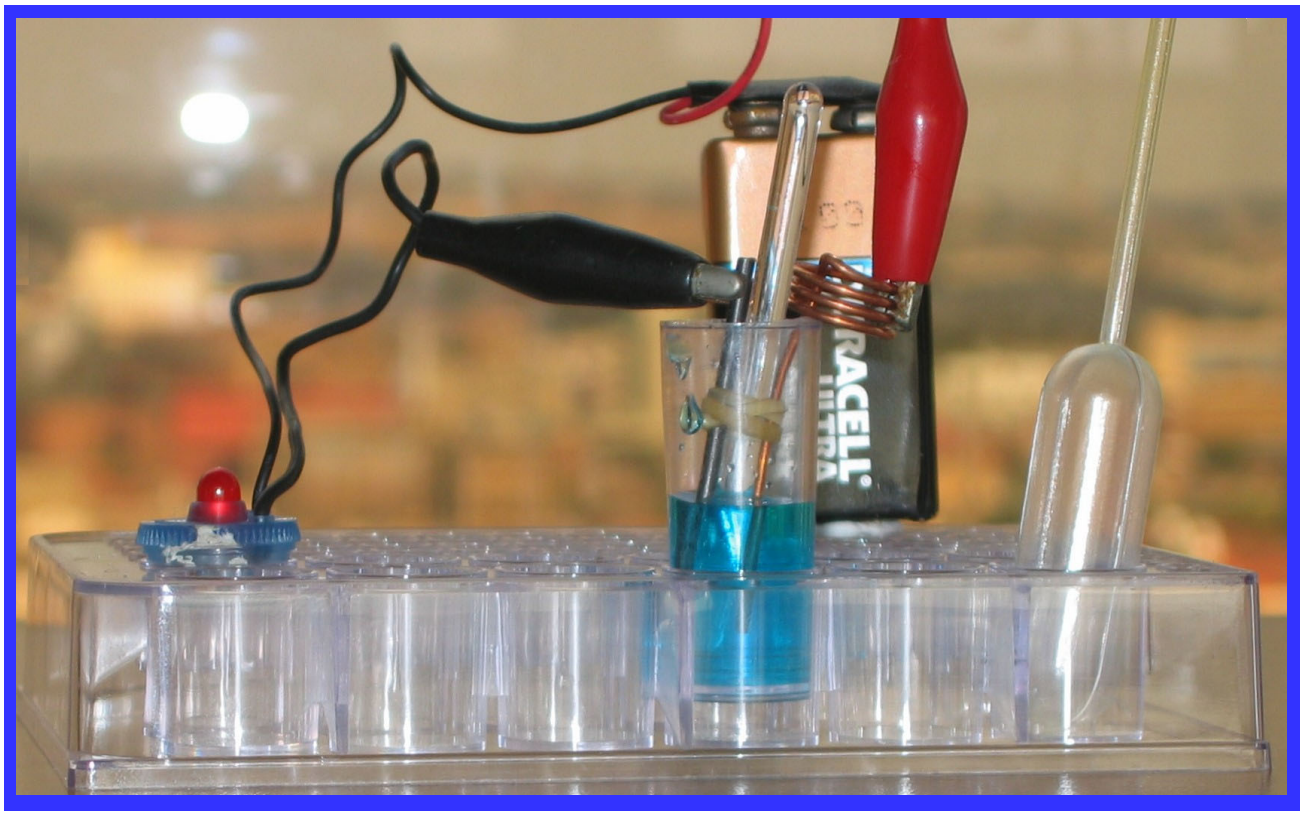
ADVANCED LEARNING PACKAGES

MICROELECTROCHEMISTRY EXPERIMENTS

Manual for Learners - First Edition



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United Nations Educational,
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The UNESCO-Associated Centre
for Microscience Experiments,
RADMASTE Centre

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ADVANCED TEACHING AND LEARNING PACKAGES

MICROELECTROCHEMISTRY

ELECTROLYSIS OF WATER

REQUIREMENTS

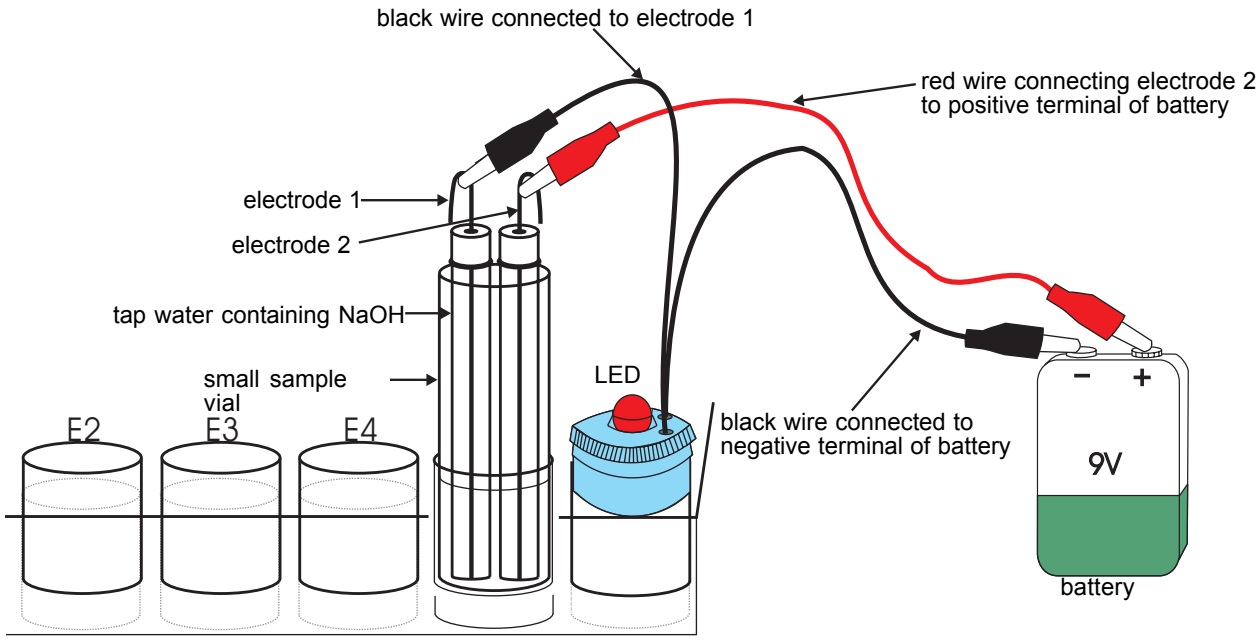
Apparatus: 1 x 9 V heavy duty battery (or 2 x 1.5 V cells); 1 x comboplate®;
1 x current indicator (LED) with wire connections; 2 x drinking straw electrodes;
1 x plastic microspatula; 1 x small sample vial; 1 x microburner; 1 x box of matches;
1 x thin stemmed propette; 1 x red coated copper wire (with exposed ends);
1 x black coated copper wire (with exposed ends); crocodile clips (optional).

Chemicals: Sodium hydroxide pellets (NaOH(s)); Tap water.

Note **Sodium hydroxide will be added to tap water in this experiment to increase the conductivity of the tap water.**

PROCEDURE

1. Push the current indicator into well E6 of the comboplate®.
2. Mark each of the drinking straw electrodes into 1 cm units using a permanent marker pen. Let one of the electrodes be called electrode 1 and the other electrode 2.
3. Remove the lid from the small sample vial and fill half of the vial with tap water. Place the vial into well E5 next to the current indicator in well E6.
4. Use the plastic microspatula to place 1 pellet of sodium hydroxide into the small sample vial and stir until it has dissolved. Use an empty propette to suck up some of the solution from the vial.
5. Hold electrode 1 with the open end upwards and fill the electrode completely with the water from the propette.
6. Quickly turn electrode 1 the other way up and place it into the water in the small sample vial. Repeat this procedure for electrode 2. Return any remaining solution in the propette to the small sample vial. Use tap water to thoroughly rinse your fingers free of the sodium hydroxide solution.
7. Connect the end of the long black wire from the current indicator to the negative (-) terminal of the battery. Connect the end of the short black wire to electrode 1.
8. Connect the one end of the red wire to the positive (+) terminal of the battery. Connect the other end of the red wire to electrode 2. *(See Question 1)*



9. Disconnect the current indicator from the circuit. Reconnect electrodes 1 and 2 directly to the negative and positive terminals of the battery with the loose connecting wires supplied. *(See Question 3)*
10. Let the substance produced in electrode 1 be called substance A. Let the substance produced in electrode 2 be called substance B. (Periodically tap each electrode with your finger, to dislodge substances A and B which may build up in localised areas.)
11. When electrode 1 is full of substance A (at the end of the last pen marking on the electrode), disconnect the battery from the circuit. This may take approximately 10 minutes (or longer if you are using two 1.5 V cells). *(See Question 4)*
12. Light the microburner. Carefully remove electrode 1 from the water, sealing the open end with your finger when it is out of the water. Bring electrode 1 very close to the flame of the microburner. Do not burn yourself or the straw!
13. Remove your finger from the opening, allowing substance A to escape. When you have observed what happens, thoroughly rinse your fingers with tap water. *(See Question 5)*

Rinse the vial out with clean water.

ELECTROLYSIS OF WATER

QUESTIONS

Q 1. What effect is there on the current indicator when the battery is connected to the electrodes ?

Q 2. What is the reason for your observation in question 1 ?

Q 3. What do you observe at the different electrodes ?

Q 4. When electrode 1 is full of substance A, how much of substance B is there in electrode 2 ?

Q 5. What happens when substance A is exposed to the flame ?

Q 6. What is the name given to substance A ?

Q 7. What is the name of substance B ?

Q 8. What test would you do to prove substance B is what you say it is ?

Q 9. Why was a greater volume of substance A produced than of substance B ?

Q10. Write a summary of what happens when water is electrolysed.

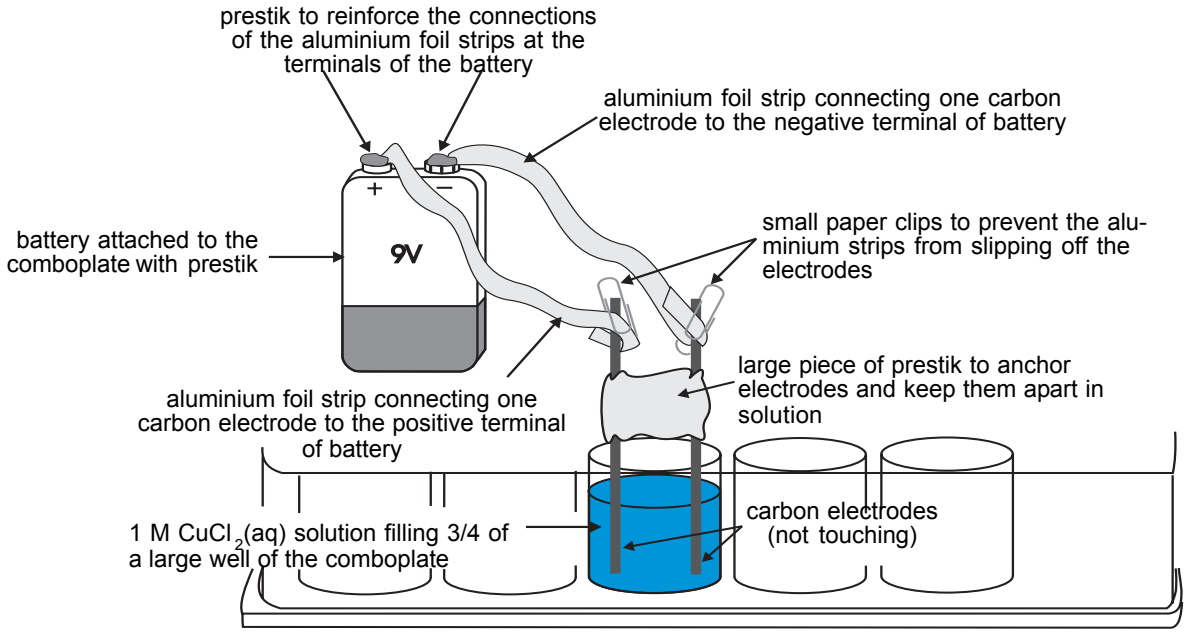
Q11. From question 10, would you say that tap water is a compound, an element or a mixture ? Explain your answer.

THE ELECTROLYSIS OF A COPPER(II) CHLORIDE SOLUTION

REQUIREMENTS

Apparatus: 1 x comboplate®; 1 x 9V battery;
2 x strips aluminium foil - 3 cm x 15 cm (or 2 x connecting wires with crocodile clips);
1 x graphite pencil or 2 x graphite rods (approximately 2 mm x 5 cm);
2 x plastic coated paper clips (optional); prestik.

Chemicals: Copper(II) chloride solution ($CuCl_2(aq)$) [1 M]; Indicator paper; Tap water.



PROCEDURE

1. Use a piece of prestik to stick the 9V battery to the comboplate®. This will prevent the battery moving around during the experiment so that the aluminium foil connectors are not pulled away from the electrodes.
2. Break open the pencil carefully and remove the graphite/carbon rod. Make two carbon electrodes by breaking or cutting the rod into two shorter pieces of approximately 5 cm each in length. Alternatively, ready-made carbon rods can be used.
3. Push one of the carbon electrodes into a large piece of prestik. Push the other electrode into the same piece of prestik. Make sure that the electrodes are far apart from one another so that they do not touch when placed into the copper chloride solution.
4. Use a clean propette to fill about ¾ of one of the large wells of the comboplate® with the 1 M copper(II) chloride solution.
5. Place the carbon electrodes in the solution as shown in the diagram above. The electrodes do not need to be held in the upright position. They can be rested at an angle against the wall of the large well.
6. Fold one of the strips of aluminium foil about three times to form a narrow but sturdy connector as shown in the diagram above. Fold the other aluminium foil strip in the same way.
7. Attach each one of the aluminium foil connectors to separate terminals of the battery. Prestik can be used to reinforce the connections to the battery. Alternatively, small crocodile clips can be used to make sure that the foil strips are properly connected to the battery terminals.
8. Connect the battery to the electrodes by attaching the aluminium foil strips from the terminals of the battery to separate carbon electrodes, as shown in the diagram. *(See Question 1)*

Note Small, plastic-coated paper clips can be used to attach the ends of each foil strip to the electrodes. This helps to prevent the foil from slipping off the electrodes during electrolysis.

9. After about one or two minutes, lift the comboplate® gently upwards towards your chin. *(See Question 2)*

CAUTION! **Do not inhale the fumes directly!**

10. Moisten a small piece of indicator paper (either litmus or universal indicator paper in the kit) with tap water.
11. Hold one corner of the paper at the electrode where there is bubbling taking place. *(See Question 3)*
12. Look closely at the other electrode in the solution and observe any changes taking place. *(See Question 4)*
13. Allow the electrolysis to continue for another 5 to 10 minutes. Disconnect the foil from the electrode where no bubbling was observed.
14. Lift the electrode out of the copper(II) chloride solution and examine its appearance. *(See Question 5)*

Clean all apparatus thoroughly.

THE ELECTROLYSIS OF A COPPER(II) CHLORIDE SOLUTION

QUESTIONS

Q1. What do you notice as soon as the battery has been connected to the electrodes?

Q2. Describe the odour coming from the well.

Q3. What happens to the section of the indicator paper that is held close to the electrode at which bubbling takes place? Is this electrode connected to the positive or negative terminal of the battery?

Q4. Describe the change in appearance of the other electrode (i.e the electrode where no bubbling occurs). Is this electrode connected to the positive or negative terminal of the battery?

Q5. What has happened to the electrode after the electrolysis of the copper(II) chloride solution has been allowed to continue for 5 to 10 more minutes?

Q6. What was happening at the electrode where you saw bubbling taking place? Use your answers to Questions 2 and 3 to support your explanation.

Q7. What was happening at the electrode where no bubbles were observed?

Q8. Describe the appearance of the copper(II) chloride solution before electrolysis took place. Do the products formed at each electrode have the same properties as the original solution? Explain your answer by referring to observations made during the experiment.

Q9. From your answer to Question 8, describe the effect of an electric current on a copper(II) chloride solution.

Q10. The carbon rods or electrodes are required for carrying current into and out of the copper(II) chloride solution. Each electrode has a special name. The electrode connected to the positive terminal of the battery is called the anode, while the electrode connected to the negative terminal of the battery is called the cathode.

i. At which electrode did chlorine gas form? (See your answer to Question 3)

ii. At which electrode did copper metal deposit? (See your answer to Question 4)

Q11. An electric current can only flow if the solution contains charged particles that are able to move through the solution. Write down the formulae of the charged particles which exist in a copper(II) chloride solution. Name the charged particles.

Q12. Recall what you observed at the anode. Which charged particles in the copper(II) chloride solution moved towards the anode?

Q13. Which charged particles moved towards the cathode? Explain by referring to the product you observed at this electrode.

Q14. Write down a balanced equation to show the reaction taking place in the well during electrolysis. What type of reaction is this? Explain your answer with reference to the observations made at each electrode.

Q15. What kind of half-reaction occurs at the anode? Write an equation for this half-reaction. (See your answers to Q10i and Q14)

Q16. What kind of half-reaction occurs at the cathode? Write an equation for this half-reaction. (See your answers to Q10ii and Q14)

CELL POTENTIALS - PART 1

THE ZINC - COPPER CELL

REQUIREMENTS

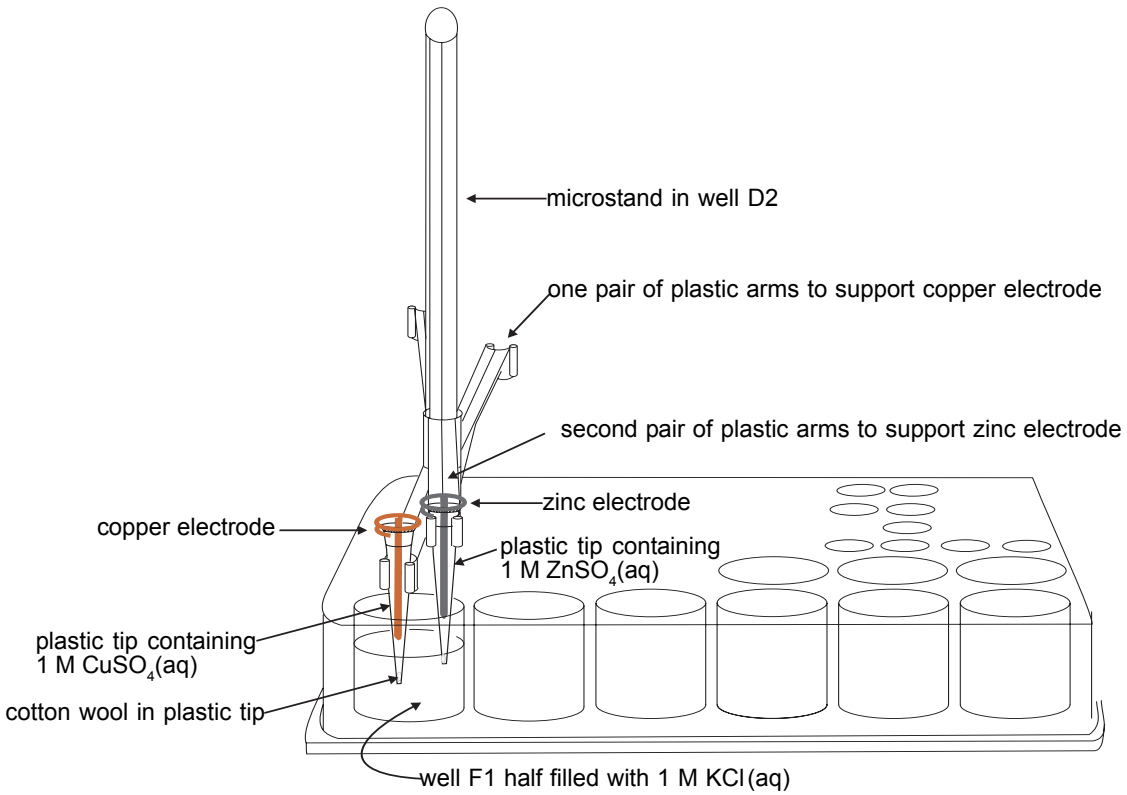
Apparatus: 1 x multimeter; connecting wires for the multimeter; 1 x copper wire electrode; 1 x zinc wire electrode; 2 x connecting wires; crocodile clips (optional); 2 x plastic tips; 1 x cotton wool ball; 1 x toothpick; 1 x propette ; 1 x comboplate® ; 1 x plastic retort stand ; 2 x plastic arms.

Chemicals: Potassium chloride solution (KCl(aq)) [1.0M] ; Copper sulphate solution ($CuSO_4$(aq)) [1.0 M]; Zinc sulphate solution ($ZnSO_4$(aq)) [1.0 M].

Note **The propette should be thoroughly cleaned by rinsing with tap water before each new solution is used. If this is not done the stock solutions will become contaminated and the experiment will be misleading.**

PROCEDURE

1. Block the narrow end of each plastic tip by pushing a small piece of cotton wool firmly into each from the top. Use the toothpick. Make sure the plastic tips are blocked properly.
2. Assemble the microstand as follows: Push the plastic retort stand into well D2 of the comboplate® . Place both the plastic arms onto the retort stand. Take both the blocked plastic tips and clip one on each of the plastic arms. Orient the plastic arms so that the end of both the plastic tips are three - quarters of the way into well F1. (See the diagram below.)
3. Use the propette to dispense potassium chloride solution into well F1 until it is half full. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1.
4. **Rinse the propette with tap water 3 or 4 times**, then use this same propette to add copper sulphate solution to one of the plastic tips until it is almost full .
5. **Rinse the propette with tap water 3 or 4 times**, then use this same propette to add the zinc sulphate solution to the second plastic tip until it is almost full .
6. Place the copper wire electrode into the copper sulphate solution. Place the zinc wire electrode into the zinc sulphate solution. (See the diagram below.)
7. Place the multimeter (set at 20 V) close to the comboplate® and connect it to the copper and zinc electrodes. *(See Question 1)*



CELL POTENTIALS - PART 1

THE ZINC - COPPER CELL

QUESTIONS

Q 1. What is the reading (V) on the multimeter ?

Q 2. Why is there a reading (V) on the multimeter ?

Q 3. At which electrode is oxidation taking place ? At which electrode is reduction taking place ?

Q 4. Which electrode is the anode and which is the cathode ?

Q 5. Write down the half equation to show what is happening at the copper electrode.

Q 6. Write down the half equation to show what is happening at the zinc electrode.

Q 7. Now write down the equation to represent the galvanic cell reaction you have set up .

Q 8. What is the function of a salt bridge in a galvanic cell ? In this experiment where is the salt bridge ?

Q 9. What is the standard reduction potential of the copper electrode ? What is the standard reduction potential of the zinc electrode ?

Q 10. What is the standard potential of the zinc - copper cell ?

Q 11. How does the standard cell potential compare with the reading (V) on the multimeter ?

CELL POTENTIALS - PART 2

ADDITIVITY

REQUIREMENTS

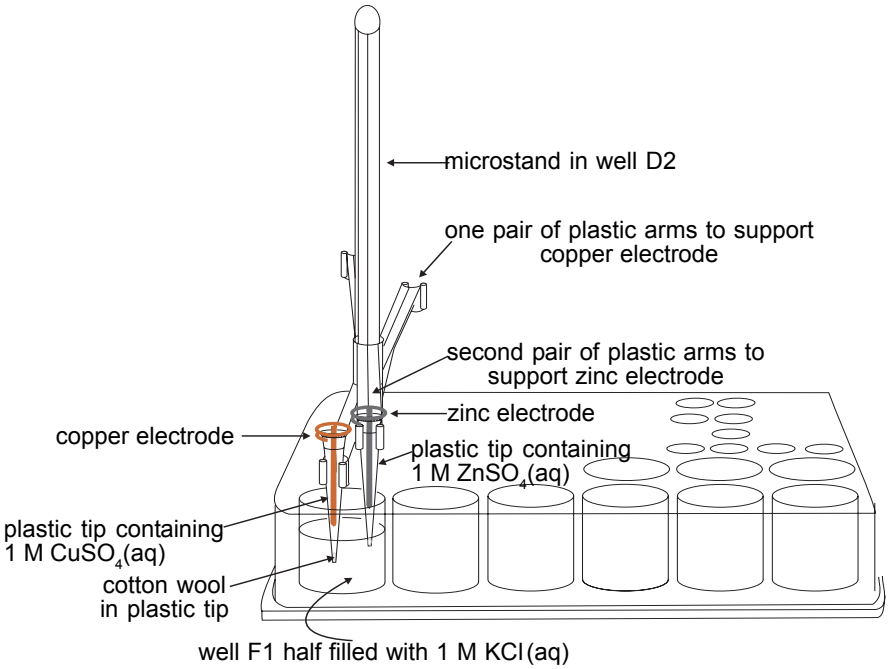
Apparatus: 1 x multimeter ; connecting wires for the multimeter; 3 x plastic tips;
1 x copper wire electrode; 1 x zinc wire electrode; 2 x connecting wires; crocodile clips (optional);
1 x cotton wool ball; 1 x toothpick; 1 x propette; 1 x lead wire electrode (or lead metal strip);
1 x comboplate® ; 1 x plastic retort stand; 2 x plastic arms.

Chemicals: Potassium chloride solution (KCl(aq)) [1.0 M] ; Copper sulphate solution ($CuSO_4$(aq)) [1.0 M];
Zinc sulphate solution ($ZnSO_4$(aq)) [1.0 M] ; Lead nitrate solution ($Pb(NO_3)_2$(aq)) [1.0 M].

Note **The propette should be thoroughly cleaned by rinsing with tap water before each new solution is used. If this is not done the stock solutions will become contaminated and the experiment will be misleading.**

PROCEDURE

1. Block the narrow end of each plastic tip by pushing a small piece of cotton wool firmly into each from the top. Use the toothpick. Make sure the plastic tips are blocked properly.
2. Assemble the microstand as follows: Push the plastic retort stand into well D2 of the comboplate®. Place both the plastic arms onto the retort stand . Take two of the blocked plastic tips and clip one on each of the plastic arms. Orient the arms so that the ends of both the plastic tips are three - quarters of the way into well F1. (See the diagram.)



3. Use the propette to dispense potassium chloride solution into well F1 until it is half full.
4. Rinse the propette with tap water 3 or 4 times, then use this same propette to add the copper sulphate solution to one of the plastic tips until it is almost full .
5. Rinse the propette with tap water 3 or 4 times, then use this same propette to add the zinc sulphate solution to the second plastic tip until it is almost full. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1.
6. Place the copper wire electrode into the copper sulphate solution. Place the zinc wire electrode into the zinc sulphate solution. (See the diagram.)
7. Place the multimeter (set at 20 V) close to the comboplate® and connect it to the copper and zinc electrodes. *(See Question 1)*
8. Disconnect the multimeter from both the electrodes. Unclip the plastic tip containing the zinc sulphate solution and place it in any one of the large wells of the comboplate®.
9. Rinse the propette with tap water 3 or 4 times, then use the same propette to add the lead nitrate solution to the third plastic tip until it is almost full. Clip this plastic tip on the same arm from which you removed the plastic tip containing the zinc sulphate solution. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1.
10. Place the lead wire electrode into the lead nitrate solution. Connect the multimeter to the copper and lead electrodes. *(See Question 3)*
11. Now disconnect the copper electrode from the multimeter. Unclip the plastic tip containing the copper sulphate solution and place the syringe in the large well of the comboplate®.
12. Take the plastic tip containing the zinc sulphate solution (which you had earlier placed in one of the wells of the comboplate®) and clip it back on the arm from which you removed the plastic tip containing the copper sulphate solution. Connect the multimeter again to both the zinc and the lead electrodes. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1. *(See Question 6)*

CELL POTENTIALS - PART 2

ADDITIVITY

QUESTIONS

Q 1. What is the reading (V) on the multimeter when the copper and zinc electrodes are connected ?

Q 2. Write down the equation for the redox reaction in the zinc - copper cell .

Q 3. What is the reading (V) on the multimeter when the copper and lead electrodes are connected ?

Q 4. Write down the equation for the redox reaction in the lead - copper cell.

Q 5. Predict what will be the reading (V) on the multimeter when the lead and zinc electrodes are connected. How did you arrive at this answer ? Show all calculations and equations .

Q 6. What is the reading (V) on the multimeter when the lead and zinc electrodes are connected ?

Q 7. Write down the equation for the redox reaction in the zinc - lead cell.

Q 8. Was your prediction for Question 5 correct ?

Q 9. What conclusion can you draw from this experiment ?

Q 10. If the standard reduction potential of the Cu/Cu^{2+} electrode is + 0.34V, deduce the standard reduction potentials of the Zn/Zn^{2+} and Pb/Pb^{2+} electrodes.

Q 11. For the redox reaction in the Zn -Cu cell what is the quantity of charge transferred per mole of reaction?

Q 12. How much work can the Zn-Cu cell perform per mole of reaction ?

Q 13. What is the standard molar free energy for the redox reaction between Zn and $Cu^{2+}(aq)$?

CELL POTENTIALS - PART 3

THE EFFECT OF CONCENTRATION

REQUIREMENTS

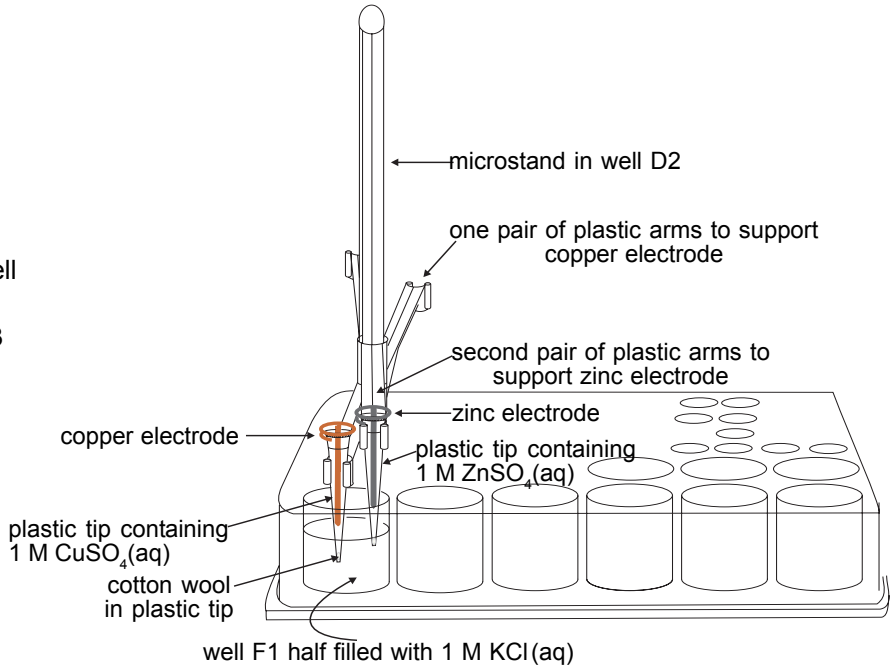
Apparatus: 1 x multimeter ; connecting wires for the multimeter; 6 x plastic tips; 1 x copper wire electrode; 1 x zinc wire electrode; 2 x connecting wires; crocodile clips (optional); 1 x cotton wool ball; 1 x toothpick; 4 x propettes; 1 x comboplate®; 1 x plastic retort stand; 2 x plastic arms.

Chemicals: Potassium chloride solution (KCl(aq)) [1.0 M];
Copper sulphate solution ($CuSO_4$(aq)) [1.0 M], [0.1 M], [0.01 M], [0.001 M];
Copper sulphate solution ($CuSO_4$(aq)) [Unknown Concentration];
Zinc sulphate solution ($ZnSO_4$(aq)) [1.0 M].

Note **The propette should be thoroughly cleaned by rinsing with tap water before each new solution is used. If this is not done the stock solutions will become contaminated and the experiment will be misleading.**

PROCEDURE

1. Block the narrow end of each plastic tip by pushing a small piece of cotton wool firmly into each from the top. Use the toothpick. Make sure the plastic tips are blocked properly.
2. Assemble the microstand as follows: Push the plastic retort stand into well D2 of the comboplate®. Place both the plastic arms onto the retort stand. Take two of the blocked plastic tips and clip one on each of the plastic arms. Orient the arms so that the ends of both the plastic tips are three - quarters of the way into well F1. (See the diagram.)
3. Use the propette to dispense potassium chloride solution into well F1 until it is half full.
4. Rinse the propette with tap water 3 or 4 times, then use this same propette to add zinc sulphate solution to one of the plastic tips until it is almost full.
5. Rinse the propette with tap water 3 or 4 times, then use this same propette to add the copper sulphate solution [1.0 M] to the other plastic tip until it is almost full. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1.



6. Place the copper wire electrode into the copper sulphate solution. Place the zinc wire electrode into the zinc sulphate solution. (See the diagram.)
7. Place the multimeter (set at 20 V) close to the comboplate® and connect it to the copper and zinc electrodes. (*See Question 1*)
8. Disconnect the multimeter from the copper electrode. Unclip the plastic tip containing the copper sulphate solution [1.0 M] and place it in any one of the large wells of the comboplate®.
9. Use a clean propette to add the copper sulphate solution [0.1 M] into a clean blocked plastic tip until it is almost full. Clip this plastic tip on the same arm from which you removed the plastic tip containing the copper sulphate solution [1.0 M].
10. Place the copper wire electrode into the copper sulphate solution [0.1 M]. Connect the multimeter to the copper and zinc electrodes and take a reading. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1. (*See Question 2*)
11. Repeat the procedure from steps 8 to 10 but instead of placing the 0.1 M copper sulphate solution into the clean plastic tip use the 0.01 M copper sulphate solution .
12. Repeat the procedure from steps 8 to 10 once more using the 0.001 M copper sulphate solution instead.
13. Repeat the procedure from steps 8 to 10 using the copper sulphate solution of unknown concentration instead. (*See Question 7*)

CELL POTENTIALS - PART 3

THE EFFECT OF CONCENTRATION

QUESTIONS

Q 1. What is the reading (V) on the multimeter ? Enter the result in a table like Table 1 below.

Q 2. Tabulate the reading on the multimeter (in mV) when the concentration of the copper sulphate solution around the copper electrode is 0.1 M, 0.01 M and 0.001 M respectively.

Table 1

$[Cu^{2+}(aq)]$ / mol dm^{-3}	Log $[Cu^{2+}(aq)]$	CELL POTENTIAL / mV
1.00		
0.100		
0.0100		
0.00100		

Q 3. Write down the equation for the reaction in the Zn - Cu cell.

Q 4. What did you observe about the reading on the multimeter as you decreased the concentration of the copper sulphate solution ?

Q 5. Draw a graph of cell potential (mV) versus concentration (mol dm^{-3}) of $Cu^{2+}(aq)$ for the Zn -Cu cell.

Q 6. For each concentration of $Cu^{2+}(aq)$ calculate the $\log_{10}$ of this concentration and enter the value in Table 1. Draw a graph of cell potential versus $\log[Cu^{2+}(aq)]$ for the Zn - Cu cell. What can you deduce from the graph ?

Q 7. What is the reading on the multimeter ? What is the concentration of copper ions in the unknown copper sulphate solution ?

Q 8. Devise a method for measuring the $Zn^{2+}(aq)$ concentration of a solution.

CELL POTENTIALS - PART 4

THE NERNST EQUATION

REQUIREMENTS

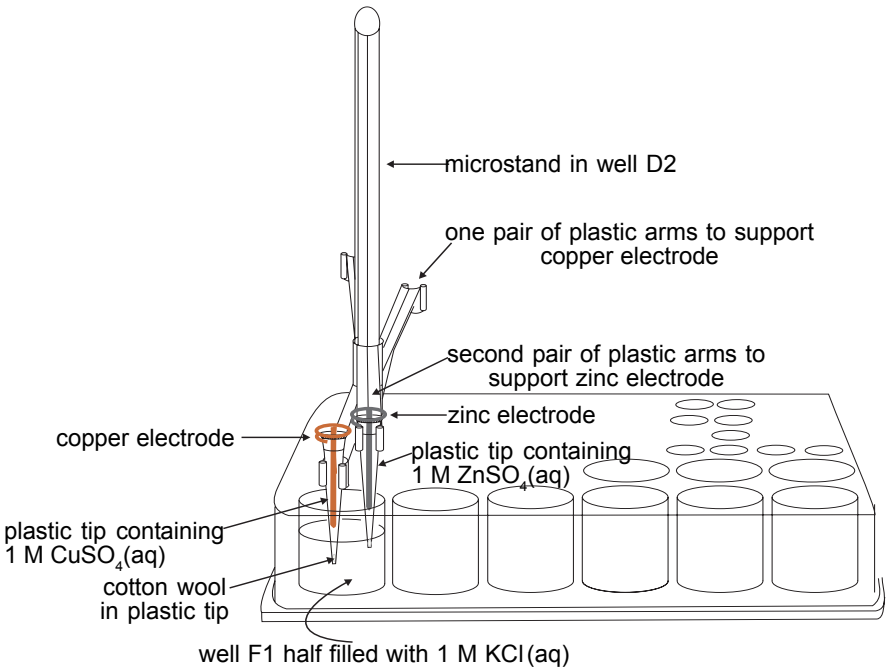
Apparatus: 1 x multimeter; connecting wires for the multimeter; 6 x plastic tips; 1 x copper wire electrode; 1 x zinc wire electrode; 2 x connecting wires; crocodile clips (optional); 1 x cotton wool ball; 1 x toothpick; 4 x propettes; 1 plastic retort stand; 2 x plastic arms; 1 x comboplate®.

Chemicals: Potassium chloride solution (KCl(aq)) [1.0 M];
Copper sulphate solution ($CuSO_4$(aq)) [1.0 M], [0.1 M], [0.01 M], [0.001 M];
Zinc sulphate solution ($ZnSO_4$(aq)) [1.0 M]; *Sodium sulphate solution (Na_2SO_4) [1.0 M].

Note **The propette should be thoroughly cleaned by rinsing with tap water before each new solution is used. If this is not done the stock solutions will become contaminated and the experiment will be misleading.**
***The sodium sulphate solution is for the teacher only.**

PROCEDURE

1. Block the narrow end of each plastic tip by pushing a small piece of cotton wool firmly into each from the top. Use the toothpick. Make sure the plastic tips are blocked properly.
2. Assemble the microstand as follows: Push the plastic retort stand into well D2 of the comboplate®. Place both the plastic arms onto the retort stand. Take 2 of the blocked plastic tips and clip one on each of the plastic arms. Orient the plastic arms so that the ends of both the plastic tips are three - quarters of the way into well F1. (See the diagram.)
3. Use the propette to dispense potassium chloride solution into well F1 until it is half full.
4. Rinse the propette with tap water 3 or 4 times, then use this same propette to add zinc sulphate solution to one of the plastic tips until it is almost full.



5. Rinse the propette with tap water 3 or 4 times, then use this same propette to add the copper sulphate solution [1.0 M] to the other plastic tip until it is almost full. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1.
6. Place the copper wire electrode into the copper sulphate solution. Place the zinc wire electrode into the zinc sulphate solution. (See the diagram.)
7. Place the multimeter (set at 20 V) close to the comboplate® and connect it to the copper and zinc electrodes. (*See Question 1*)
8. Disconnect the multimeter from the copper electrode. Unclip the plastic tip containing the copper sulphate solution [1.0 M] and place it in any one of the large wells of the comboplate®.
9. Use a clean propette to add the copper sulphate solution [0.1 M] into a clean blocked plastic tip until it is almost full. Clip this plastic tip on the same arm from which you removed the plastic tip containing the copper sulphate solution [1.0 M].
10. Place the copper wire electrode into the copper sulphate solution [0.1 M]. Connect the multimeter to the copper and zinc electrodes and take a reading. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1. (*See Question 2*)
11. Repeat the procedure from steps 8 to 10 but, instead of placing the 0.1 M copper sulphate solution into the clean plastic tip use the 0.01 M copper sulphate solution.
12. Repeat the procedure from steps 8 to 10 once more, using the 0.001 M copper sulphate solution instead.

CELL POTENTIALS - PART 4

THE NERNST EQUATION

QUESTIONS

Q 1. What is the reading (V) on the multimeter ? Enter the result in a table like Table 1 below.

Q 2. Tabulate (Table 1) the reading on the multimeter, ie. the Cell Potential, E (in mV) when the concentration of the copper sulphate solution around the copper electrode is 0.1 M, 0.01 M and 0.001 M respectively.

Table 1

$[Cu^{2+}(aq)]$ / mol dm^{-3}	OBSERVED CELL POTENTIAL, E / mV	$Log[Cu^{2+}aq)]$	lnQ	EXPECTED CELL POTENTIAL, E /mV
1.00				
0.100				
0.0100				
0.00100				

Q 3. Draw a graph of cell potential E (mV) versus concentration (mol dm^{-3}) of $[Cu^{2+}(aq)]$ for the Zn - Cu cell.

Q 4. Compare your graph with the one drawn for Question 5 in the previous experiment, ie: Part 3.

Q 5. For each concentration of $Cu^{2+}(aq)$ calculate the $\log_{10}$ of this concentration and enter the value in Table 1. Draw a graph of cell potential versus log $[Cu^{2+}(aq)]$ for the Zn - Cu cell. Compare your graph with the one drawn for Question 6 in the previous experiment, ie. Part 3.

Q 6. State the Nernst Equation and the numerical value of E^0, R, T and F under standard conditions.

Q 7. What does the quantity Q stand for in the Nernst Equation ?

Q 8. Calculate lnQ for the various copper sulphate solutions and add the values to Table 1.

Q 9. Using the Nernst Equation calculate the expected E for each of the $Cu^{2+}(aq)$ concentrations and enter it in Table 1.

Q10. Compare the expected and the experimental values of E.

GALVANISING

REQUIREMENTS

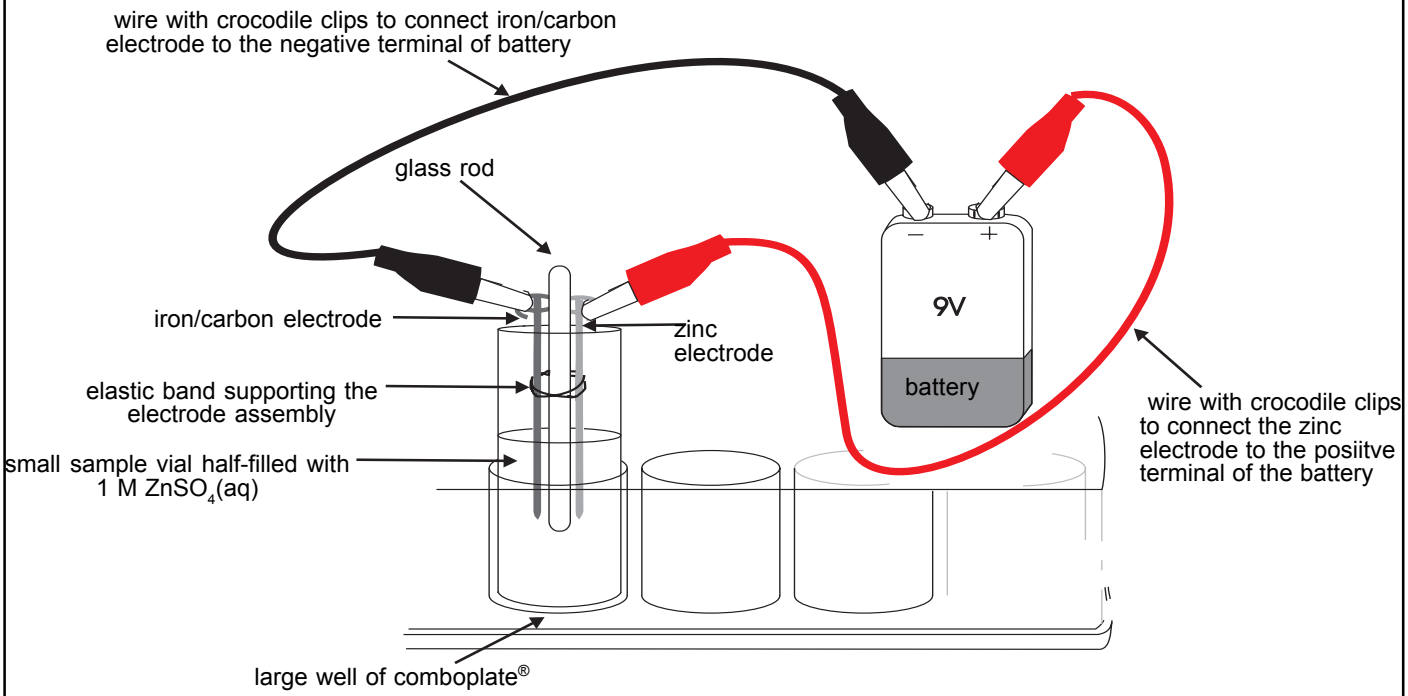
Apparatus: 1 x galvanised iron wire electrode; 1 x iron wire electrode; 1 x carbon electrode - 1.5 cm x 2 mm; 1 x small sample vial; 1 x 9 V heavy duty battery (or 2 x 1.5 V cells); 2 x connecting wires; 4 x crocodile clips; 1 x comboplate®; 1 x thin stemmed propette; 1 x glass rod; 1 x small elastic band.

Chemicals: Zinc sulphate solution ($ZnSO_4(aq)$) [1.0 M]

Note **Galvanised iron wire is iron wire coated with zinc.**

PROCEDURE

1. Use a clean propette to dispense the zinc sulphate solution into the small sample vial until it is half full. Place the sample vial into any one of the large wells of the comboplate®. Place it on one side.
2. The electrode assembly is made as follows: Hold the glass rod in one hand. Place the zinc electrode along the one side of the glass rod and the iron electrode along the other side of the glass rod. Hold them in place with the elastic band. The glass rod prevents the electrodes from touching one another during the galvanising process.
3. Using the connecting wires, connect the positive terminal of the battery to the zinc electrode and the negative terminal of the battery to the iron electrode .
4. Place the electrode assembly into the vial containing the zinc sulphate solution.(See the diagram below.)
5. After 1 minute remove the electrode assembly from the zinc sulphate solution.(*See Question 1*)
6. Detach the iron electrode from the electrode assembly and attach the carbon electrode in its place.
7. Place the electrode assembly once again into the vial containing the zinc sulphate solution .
8. After 1 minute remove the electrode assembly from the zinc sulphate solution. (*See Questions 6 & 7*)



QUESTIONS

Q1. What can you observe on the iron electrode ?
Q2. Briefly explain your observation in Question 1.
Q3. Which electrode is the anode and which is the cathode ?
Q4. Write down the half - reaction equation to show what happened at the zinc electrode.
Q5. Write down the half - reaction equation to show what happened at the iron electrode.
Q6. What can you observe on the carbon electrode ?
Q7. Rub your finger against the carbon electrode where it was in the zinc sulphate solution. What do you observe?
Q8. What is galvanising ?

ELECTROPLATING OF COPPER

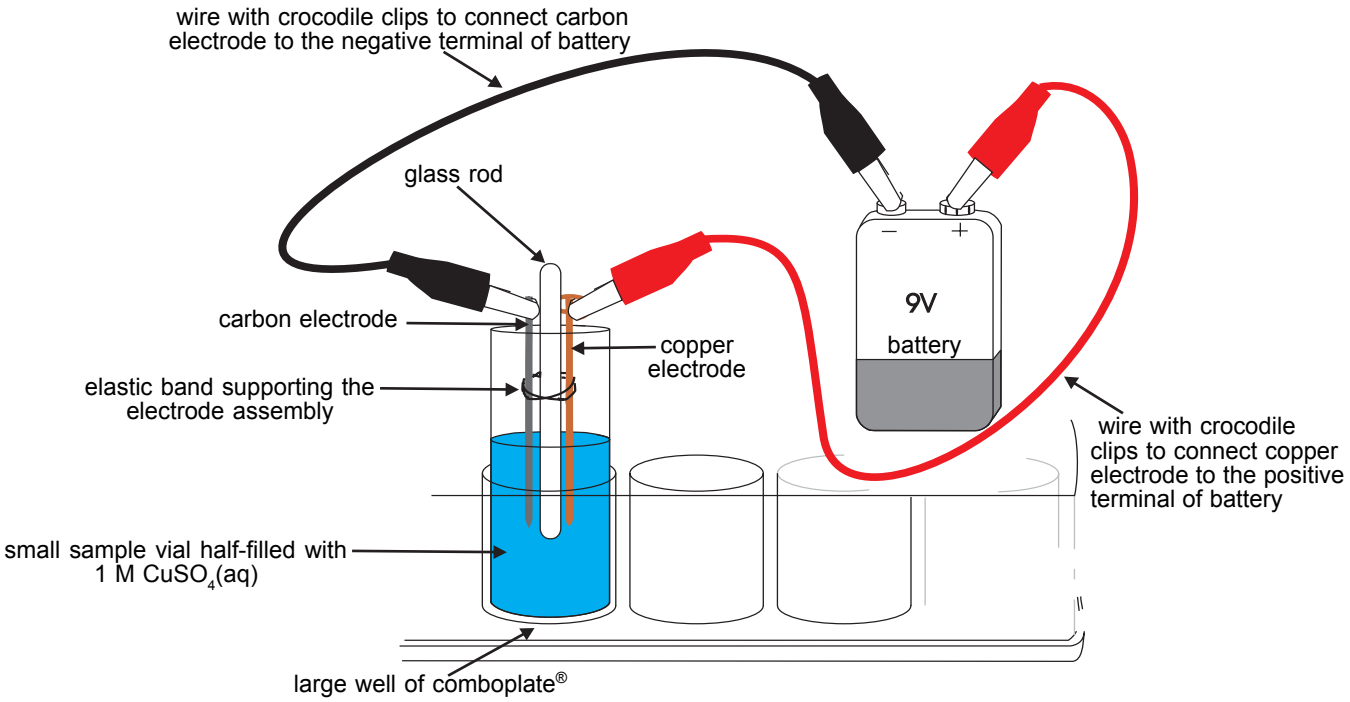
REQUIREMENTS

Apparatus: 1 x copper wire electrode; 1 x carbon electrode (pencil lead);
1 x 9 V heavy duty battery (or 2 x 1.5 V cells); 2 x connecting wires; 4 x crocodile clips;
1 x small sample vial; 1 x comboplate®; 1 x thin stemmed propette; 1 x glass rod;
1 x small elastic band.

Chemicals: Copper sulphate solution ($CuSO_4(aq)$) [1.0 M]

PROCEDURE

1. Use a clean propette to dispense the copper sulphate solution into the small sample vial until it is half full. Place the sample vial into any one of the large wells of the comboplate®. Place it on one side.
2. The electrode assembly is made as follows: Hold the glass rod in one hand. Place the carbon electrode along the one side of the glass rod and the copper wire electrode along the other side of the glass rod. Hold them in place with the elastic band. The glass rod prevents the electrodes from touching one another during electroplating.
3. Using the connecting wires, connect the positive terminal of the battery to the copper electrode and the negative terminal of the battery to the carbon electrode.
4. Place the electrode assembly into the sample vial containing the copper sulphate solution. (See the diagram below.)
5. After 1 minute remove the electrode assembly from the copper sulphate solution.(*See Question 1*)



QUESTIONS

Q1. What can you observe on the carbon electrode ?

Q2. Briefly explain your observation in Question 1.

Q3. Which electrode is the anode and which is the cathode ?

Q4. Write down the half - reaction equation to show what happened at the copper electrode.

Q5. Write down the half - reaction equation to show what happened at the carbon electrode.

Q6. What are the requirements for electroplating in terms of the setup ?

THE OXIDISING POWER OF Fe^{3+}, MnO_4^- and $Cr_2O_7^{2-}$

REQUIREMENTS

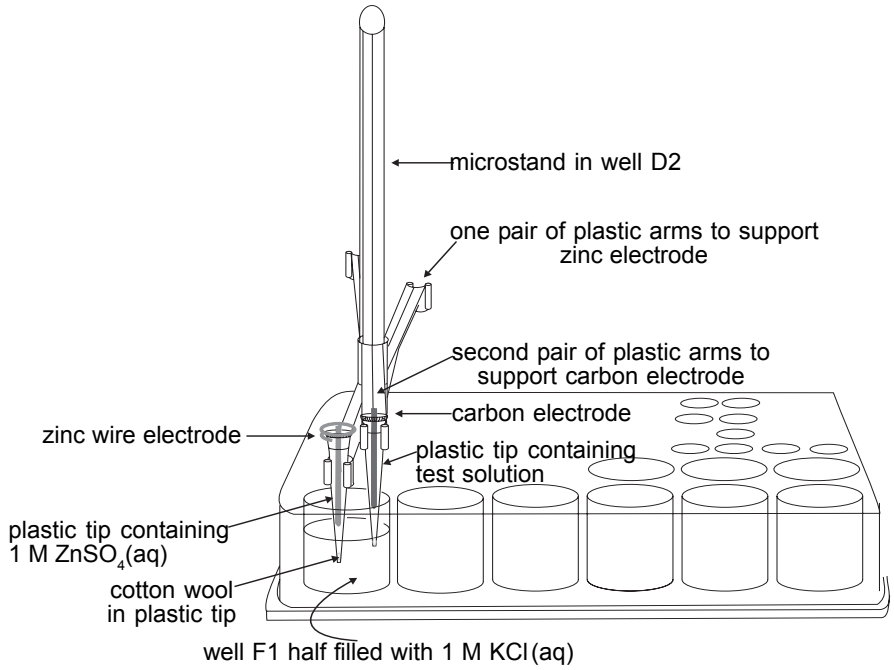
Apparatus: 1 x multimeter ; connecting wires for the multimeter; 4 x plastic tips ;
1 x zinc wire electrode; 1 x carbon electrode (pencil lead); 1 x cotton wool ball ; 1 x toothpick;
4 x propettes; 1 x electrical connecting wire - 10 cm; crocodile clips (optional); 1 x plastic retort stand;
2 x plastic arms; 1 x comboplate® .

Chemicals: Potassium chloride solution (KCl(aq)) [1.0 M];
Ferrous ammonium sulphate solution ($Fe(NH_4)_2(SO_4)_2$ (aq)) [2.0 M];
Ferric ammonium sulphate solution ($Fe(NH_4)(SO_4)_2$ (aq)) [2.0 M];
Acidified potassium permanganate solution ($KMnO_4$(aq)) [2.0 M];
Manganese sulphate solution ($MnSO_4$(aq)) [2.0 M];
Acidified potassium dichromate solution ($K_2Cr_2O_7$(aq)) [2.0 M];
Chromic sulphate solution ($Cr_2(SO_4)_3$(aq)) [2.0 M]; Zinc sulphate solution ($ZnSO_4$(aq)) [1.0 M].

Note **The propette should be thoroughly cleaned by rinsing with tap water before each new solution is used. If this is not done the stock solutions will become contaminated and the experiment will be misleading.**

PROCEDURE

1. Block the narrow end of each plastic tip using the cotton wool and the toothpick. Make sure the plastic tips are blocked properly.
2. Assemble the microstand as follows: Push the plastic retort stand into well D2 of the comboplate®. Place both the plastic arms onto the retort stand. Take two of the blocked plastic tips and clip one on each of the plastic arms. Orient the plastic arms so that the ends of both the plastic tips are three - quarters of the way into well F1. (See the diagram.)
3. Use the propette to dispense potassium chloride solution into well F1 until it is half full.
4. Use a clean propette to add zinc sulphate solution to one of the plastic tips until it is almost full.



5. Use a clean propette to add the ferrous ammonium sulphate solution to the second plastic tip until it is half full. Rinse the propette with tap water 3 or 4 times, then use this same propette to add the ferric ammonium sulphate solution into the same plastic tip until it is almost full. Make sure the ends of both the plastic tips are immersed into the potassium chloride solution in well F1.
6. Place the multimeter (set at 20 V) close to the comboplate®. Take the electrical connecting wire and connect the one end to the carbon electrode and the other end to the multimeter. Place the unattached end of the carbon electrode into the plastic tip containing the ferric ammonium/ferrous ammonium sulphate solution. (See the diagram.)
7. Place the zinc wire electrode into the zinc sulphate solution and connect it to the multimeter.(*See Question 1*)
8. Remove the carbon electrode from the ferric ammonium/ferrous ammonium sulphate solution and rinse it with tap water. (This can be done with the one end of the carbon electrode connected to the electrical connecting wire - make sure you do not let any tap water touch the electrical wire.) Unclip the plastic tip containing the ferric ammonium/ferrous ammonium sulphate solution from the plastic arm and place it in any one of the large wells of the comboplate®.
9. Clip a clean blocked plastic tip into the arm from which you removed the plastic tip. Use a clean propette to add the acidified potassium permanganate solution to this plastic tip until it is half full. Rinse the propette with tap water 3 or 4 times, then use this same propette to add the manganese sulphate solution into the same plastic tip until it is almost full.
10. Place the unattached end of the carbon electrode into the plastic tip containing the MnO_4^- / Mn^{2+} solution. *(See Question 7)*
11. Repeat the procedure from steps 8 to 10, but this time place the acidified potassium dichromate solution and chromic sulphate solution into the clean plastic tip instead. *(See Question 11)*

THE OXIDISING POWER OF Fe^{3+}, MnO_4^- and $Cr_2O_7^{2-}$

QUESTIONS

Q1. What is the reading (V) on the multimeter in V?

Q2. Which electrode is the anode and which is the cathode ?

Q3. Write down the half-reaction equation to show what is happening at the zinc electrode.

Q4. Write down the half - reaction equation to show what is happening at the Fe^{3+} , Fe^{2+} / C electrode.

Q5. Now write down the equation to represent the galvanic cell reaction you have set up in steps 3 - 6.

Q6. Given that the standard reduction potential of the zinc electrode is - 0.76 V, what is the standard reduction potential of the Fe^{3+}, Fe^{2+} / C electrode ?

Q7. What is the reading (V) on the multimeter ?

Q8. Write down the half-reaction equation to show what is happening at the H^+, MnO_4^- , Mn^{2+} / C electrode.

Q9. Write down the equation to represent the galvanic cell reaction you have set up in steps 9 - 10.

Q10. What is the standard reduction potential of the H^+ , MnO_4^- , Mn^{2+} / C electrode ?

Q11. What is the reading (V) on the multimeter ?

Q12. Write down the half-reaction equation to show what is happening at the H^+, $Cr_2O_7^{2-}$, Cr^{3+} / C electrode.

Q13. Write down the equation to represent the galvanic cell reaction you have set up in step 10.

Q14. What is the standard reduction potential of the H^+, $Cr_2O_7^{2-}$, Cr^{3+} / C electrode ?

Q15. Fe^{3+}, $Cr_2O_7^{2-}$ and MnO_4^- are all oxidising agents. Rank them in order from the strongest to the weakest oxidising agent .

Q16. What is the function of the carbon electrode in this experiment ?

THE HYDROGEN - OXYGEN FUEL CELL

REQUIREMENTS

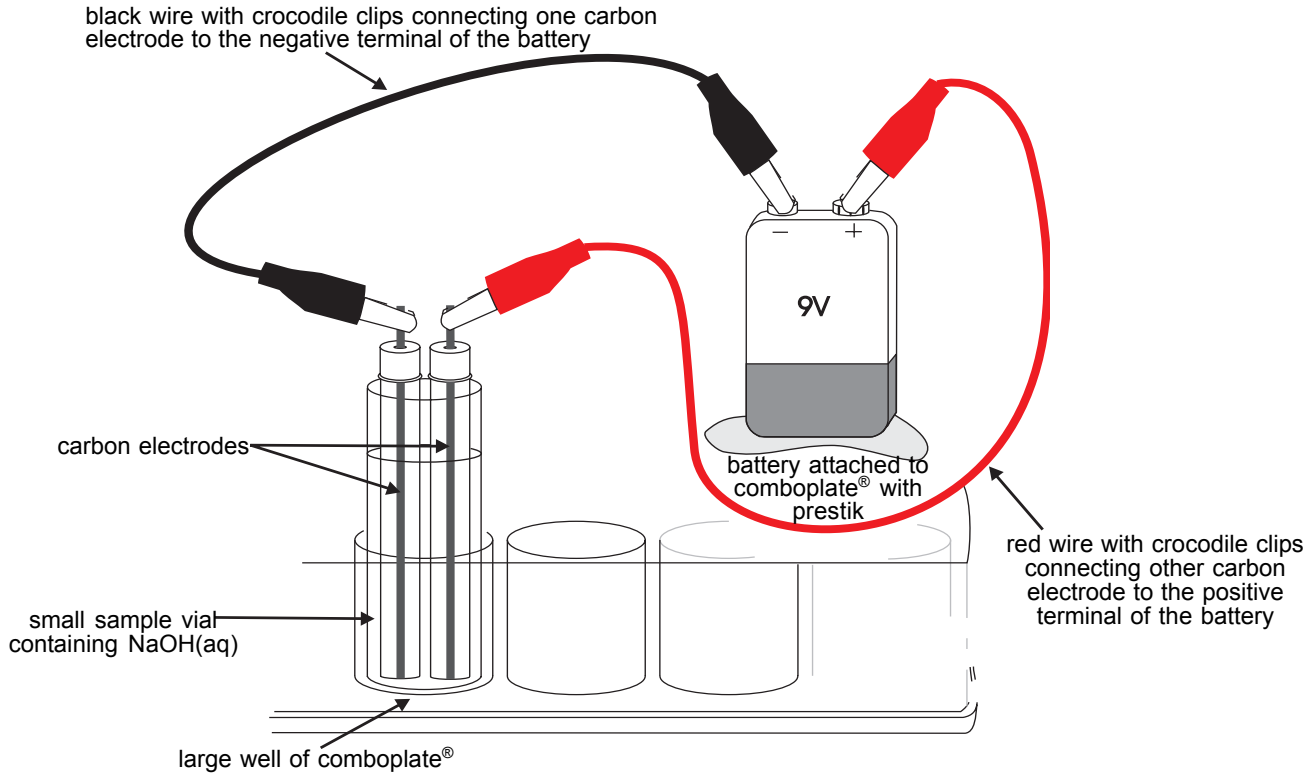
Apparatus: 1 x 9 V heavy duty battery (or 2 x 1.5 V cells); 1 x red coated copper connecting wire; 1 x black coated copper connecting wire; 4 x crocodile clips; 1 x comboplate®; 2 x drinking straw electrodes (with 2 x carbon /graphite rods - 7 cm); 1 x plastic microspatula; 1 x small sample vial; 1 x thin stemmed propette; 1 x piece of prestik; 1 x multimeter; Connecting wires for the multimeter.

Chemicals: Sodium hydroxide pellets (NaOH(s)); Tap water.

Note **Sodium hydroxide will be added to tap water in this experiment to increase the conductivity of the tap water.**

PROCEDURE

1. Remove the lid from the small sample vial and fill three -quarters of the vial with tap water. Place the vial into well E5 .
2. Use the plastic microspatula to place 15 pellets of sodium hydroxide into the small sample vial and stir until it has dissolved. Use an empty propette to suck up some of the solution from the vial.
3. Hold one straw electrode with the open end upwards and fill the electrode completely with the solution from the propette.
4. Turn the electrode the other way up and place it into the water solution in the small sample vial. Repeat this procedure for the second electrode. Make sure both the electrodes are filled to the top with the solution when they are placed in the small sample vial. Return any remaining solution in the propette to the small sample vial. Use tap water to thoroughly rinse your fingers free of the sodium hydroxide solution.
5. Connect the end of the black wire to one of the carbon electrodes and the end of the red wire to the other carbon electrode. Connect the free ends of the wires to the battery (the battery can be attached to the comboplate® using the prestik). See diagram below. (*See Question 1*)
6. When one of the carbon electrodes is full of the gas produced in it, disconnect both the carbon electrodes from the battery.
7. Immediately connect the multimeter (set at 20 V) to both the carbon electrodes. (*See Question 4*)



THE HYDROGEN - OXYGEN FUEL CELL

QUESTIONS

Q1. What do you observe when the battery is connected to the carbon electrodes ?

Q2. What do you call the chemical reaction that is observed in Question 1? Write the chemical equations for the reactions that occur at the anode, the cathode and for the overall reaction.

Q3. Which substance is produced in the carbon electrode that fills up first ? Give a reason for your answer.

Q4. What is the reading on the multimeter ?

Q5. What is the cell reaction for which the potential has been measured ?

Q6. What is the standard potential of this cell reaction ? Show your reasoning.

Q7. How does your answer in Question 6 compare with the reading on the multimeter ?

Q8. What is a fuel cell ? How can the H_2/O_2 cell function as a fuel cell ?

USING CONDUCTIVITY TO DISTINGUISH BETWEEN METALS AND NON METALS

REQUIREMENTS

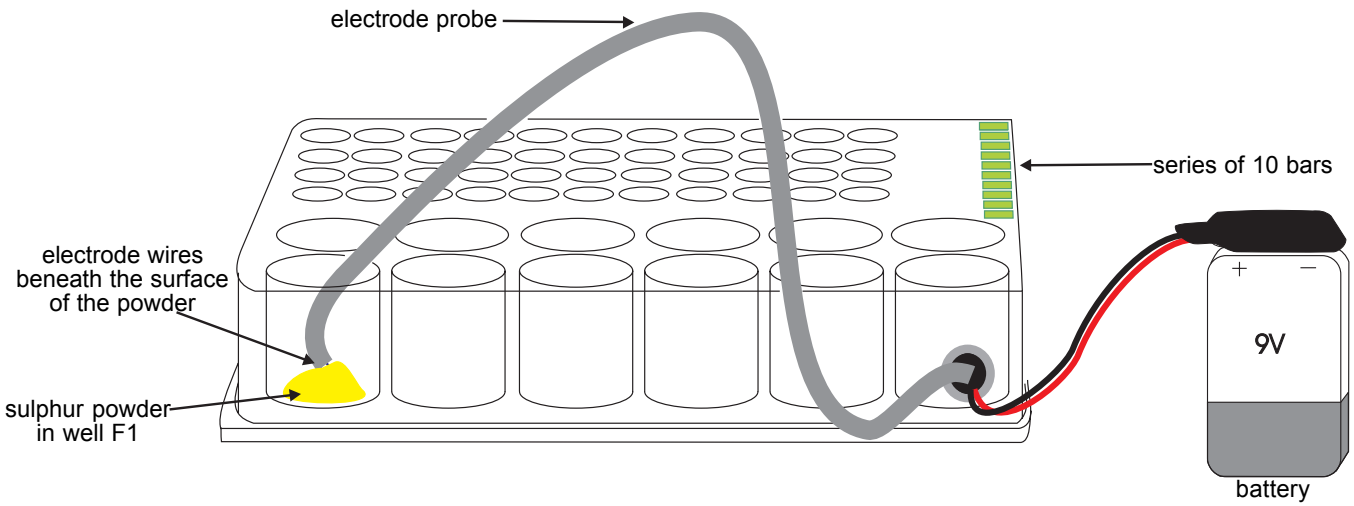
Apparatus: 1 x bar LED conductivity indicator; 1 x 9 V battery; 2 x plastic microspatulas; 1 x pencil lead (C(s) - graphite); 1 x piece of sandpaper; Paper towel.

Chemicals: Magnesium ribbon (Mg(s)); Lead metal strip (Pb(s)); Iron nail (Fe(s)); Copper metal strip (Cu(s)); Nickel metal strip (Ni(s)); Zinc metal coil (Zn(s)); Aluminium foil (Al(s)); Sulphur powder (S(s)); Iodine crystals (I_2(s)).

Make sure that you close the container with the iodine immediately after removing your crystal because the fumes escaping from the container are poisonous if inhaled.

PROCEDURE

1. Connect the bar LED conductivity indicator to the 9V battery by means of the battery clip attached to the connecting wires of the indicator.
2. Cut a piece of magnesium ribbon so that it is approximately 2.5 cm in length.
3. If the ribbon appears dull or is powdery, use a small piece of sandpaper to rub the ribbon until it shines.
4. Hold the thin electrodes protruding from the end of the electrode probe flat against the magnesium ribbon. Do not place the tips of the electrodes at the metal surface as the electrical contact will be weak, and the bar LED will flick on and off. Wait a few seconds and then observe the number of bars that light up. (*See Question 1*)
5. Wipe the electrodes gently with paper towel.
6. Hold the electrodes flat against the lead strip. Remember to sandpaper the strip if it appears dull. Observe the number of lit bars. (*See Question 1*)
7. Wipe the electrodes gently with paper towel and then repeat step 7 with an iron nail, a copper strip, a nickel strip, a zinc coil and a piece of aluminium foil. Observe the number of lit bars with each material tested. (*See Question 1*)
8. Use the spooned end of a plastic microspatula to place two heaped spatulas of sulphur powder into well F1 of the bar LED conductivity indicator.
9. Push the electrodes into the sulphur powder in the well. **DO NOT TOUCH THE BOTTOM OF THE WELL** with the electrodes as this may cause electrode damage. (See diagram below)
10. Observe the number of lit bars. Wipe the electrodes free of any sulphur powder that may cling to them. (*See Question 1*)
11. Use the spooned end of another microspatula to place one medium-sized iodine crystal into well F3.
12. Hold the electrodes against the iodine crystal in the well. If the crystal is too small such that only one of the electrodes makes contact with it, choose a larger crystal and observe the number of lit bars when both electrodes are touching the crystal. Do not let the electrodes touch the plastic of the well. (*See Question 1*)
13. Wipe the electrodes gently with paper towel. Remove a small portion of the carbon rod (graphite) from the inside of an ordinary lead pencil.
14. Hold the electrodes flat against the carbon and observe the number of lit bars. (*See Question 1*)



USING CONDUCTIVITY TO DISTINGUISH BETWEEN METALS AND NON METALS

QUESTIONS

Q1. Prepare a table like Table 1 below and record your observations there.

TABLE 1: THE CONDUCTIVITY OF SOME METALS AND NON METALS USING THE BAR LED CONDUCTIVITY INDICATOR

MATERIAL TESTED	NUMBER OF BARS GLOWING
Magnesium	
Lead	
Iron	
Copper	
Nickel	
Zinc	
Aluminium	
Sulphur	
Iodine	
Carbon	

Q2. What do you notice about all the substances tested?

(Hint: are they elements, compounds or mixtures?)

Q3. Which substance/s tested conduct electricity?

Q4. Which substance/s tested do not conduct electricity?

Q5. What is the difference between the conductors and non-conductors of electricity?

Q6. What is special about carbon (graphite)?

USING CONDUCTIVITY TO DISTINGUISH BETWEEN IONIC AND COVALENT COMPOUNDS

REQUIREMENTS

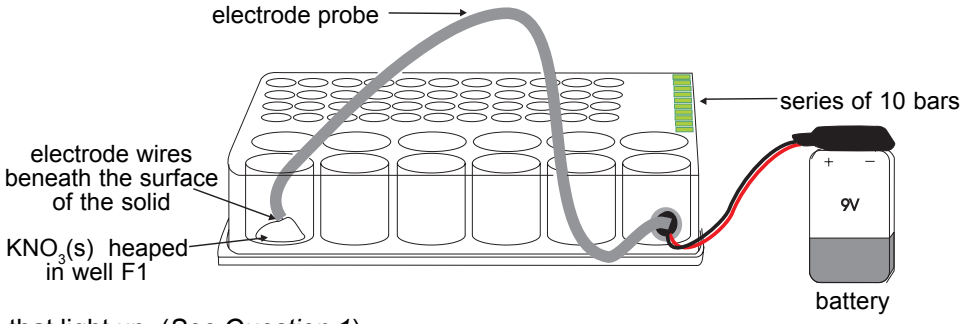
Apparatus: 1 x bar LED conductivity indicator; 1 x 9 V battery; 1 x comboplate®; 3 x plastic microspatulas; 1 x 2 ml syringe; Paper towel; 1 x paper cup.

Chemicals: Pure solid potassium nitrate ($KNO_3(s)$); Pure solid sucrose ($C_{12}H_{22}O_{11}(s)$); Pure solid sodium chloride (NaCl(s)); Deionised water.

It is extremely important not to leave the electrodes in the solution for more than a few seconds at a time. If the electrodes are left in the solution, electrolysis may occur and affect the conductivity measured. If you see bubbling around the electrodes, immediately remove the probe from the solution.

PROCEDURE

1. Connect the bar LED conductivity indicator to the 9V battery by means of the battery clip attached to the connecting wires of the indicator.
2. Make sure that the wells of your comboplate® are entirely clean and dry by rinsing with a little deionised water and drying thoroughly with paper towel.
3. Use the spooned end of a clean microspatula to place three level spatulas of pure, solid potassium nitrate ($KNO_3(s)$) into well F1. Be careful not to spill any of the solid into adjacent wells. If spillage does occur, the affected wells may not be used in the steps that follow.
4. Use the spooned end of another microspatula to place three level spatulas of pure, solid sucrose ($C_{12}H_{22}O_{11}(s)$) into well F2. If some of the $KNO_3(s)$ spilled into F2 during the previous step, use well F3 instead.
5. Use the spooned end of another microspatula to place three level spatulas of pure, solid sodium chloride NaCl(s) into well F3. If some of the sucrose spilled into F3 or F4 during the previous step, use well F5 instead.
6. Use the first microspatula to heap the $KNO_3(s)$ in well F1. Carefully insert the electrodes into the heap of $KNO_3(s)$. (See the diagram.) **Do not push the electrodes against the bottom of the well as this will cause electrode damage.**



   Observe the number of bars that light up. (*See Question 1*)
7. Wipe the electrodes gently with paper towel to remove any $KNO_3(s)$ which may cling to them.
8. Use the second microspatula to heap the sucrose in well F2. Carefully insert the electrodes into the heap of sucrose as before. Observe the number of lit bars. (*See Question 1*)
9. Wipe the electrodes gently with paper towel to remove any particles of sucrose. Repeat steps 8 and 9 with the NaCl(s) in well F3.
10. Fill a clean, dry 2 ml syringe with 2 ml of deionised water. Dispense the water into well F1 containing $KNO_3(s)$. **Do not let any part of the syringe touch the solution in well F1 as this will lead to contamination of the other solutions in the steps that follow.**
11. Use the first microspatula to stir the solution in F1 until all of the $KNO_3(s)$ has dissolved.
12. Refill the syringe with 2 ml of deionised water. Dispense the water into well F2 containing the sucrose. Use the second microspatula to stir the solution in F2 until all of the sucrose has dissolved.
13. Repeat step 12 with the NaCl(s) in well F3 and use the third microspatula to stir the solution.
14. Carefully immerse the electrodes in the centre of the potassium nitrate solution ($KNO_3(aq)$) in well F1. Make sure that the electrodes at the end of the probe are beneath the surface of the solution, but **do not push the electrodes against the bottom of the well**. Wait a few seconds and then observe the number of bars that light up. (*See Question 1*)
15. Remove the electrodes from the solution and rinse the electrodes with deionised water. Allow the waste from the rinsing to fall into the paper cup. Dry the electrodes carefully with paper towel.
16. Immerse the clean, dry electrodes into the centre of the sucrose solution ($C_{12}H_{22}O_{11}(aq)$). Wait a few seconds and then observe the number of bars that light up. (*See Question 1*)
17. Rinse the electrodes with deionised water and dry as before.
18. Repeat steps 16 and 17 with the sodium chloride solution (NaCl(aq)) in well F3.

USING CONDUCTIVITY TO DISTINGUISH BETWEEN IONIC AND COVALENT COMPOUNDS

QUESTIONS

Q1. Prepare a table like Table 1 below and record your observations there.

TABLE 1: THE CONDUCTIVITY OF SOME SOLIDS AND THEIR SOLUTIONS USING THE BAR LED CONDUCTIVITY INDICATOR

SUBSTANCE TESTED	CONDUCTIVITY/NUMBER OF BARS GLOWING
$KNO_3(s)$	
$C_{12}H_{22}O_{11}(s)$	
NaCl(s)	
$KNO_3(aq)$	
$C_{12}H_{22}O_{11}(aq)$	
NaCl(aq)	

Q2. Which of the solids conducts electricity?

Q3. Which solution/s tested conducts electricity?

Q4. Which solution/s do not conduct electricity?

Q5. Why do some solutions conduct electricity and some do not?

Q6. Why do the solutions NaCl(aq) and $KNO_3(aq)$ conduct electricity whereas their crystals do not?

Q7. Why do both the sucrose crystals and the sucrose solution fail to conduct an electric current?

Q8. Which of the compounds tested, would you describe as ionic and which as covalent?

THE CONDUCTIVITY OF SOME LIQUIDS

REQUIREMENTS

Apparatus: 1 x bar LED conductivity indicator; 1 x 9 V battery; 1 x comboplate®; 6 x thin stemmed propettes; Paper towel; 1 x paper cup.

Chemicals: Cyclohexane (C_6H_{12}(l)); Cyclohexene (C_6H_{10}(l)); Ethanol (C_2H_5OH(l)); Glycerine($HOCH_2CH(OH)CH_2OH$(l)); Tap water; Distilled water; Deionised water

Note **It is extremely important not to leave the electrodes in the liquid for more than a few seconds at a time. If the electrodes are left in the liquid, electrolysis may occur and affect the conductivity measured. If you see bubbling around the electrodes, immediately remove the probe from the liquid.**

PROCEDURE

1. Connect the bar LED conductivity indicator to the 9V battery by means of the battery clip attached to the connecting wires of the indicator.
2. Make sure that the wells of your comboplate® are entirely clean and dry by rinsing with a little deionised water and drying thoroughly with paper towel.
3. Use a clean, dry propette to fill two thirds of well F1 with tap water.
4. Use another propette to fill two thirds of well F2 with distilled water.
5. Use a third propette to fill two thirds of well F3 with deionised water.
6. Use a fourth propette to fill two thirds of well F4 with cyclohexane (C_6H_{12}(l)).

CAUTION! **Close the bottle of cyclohexane as soon as you have finished dispensing it. The fumes are poisonous!**

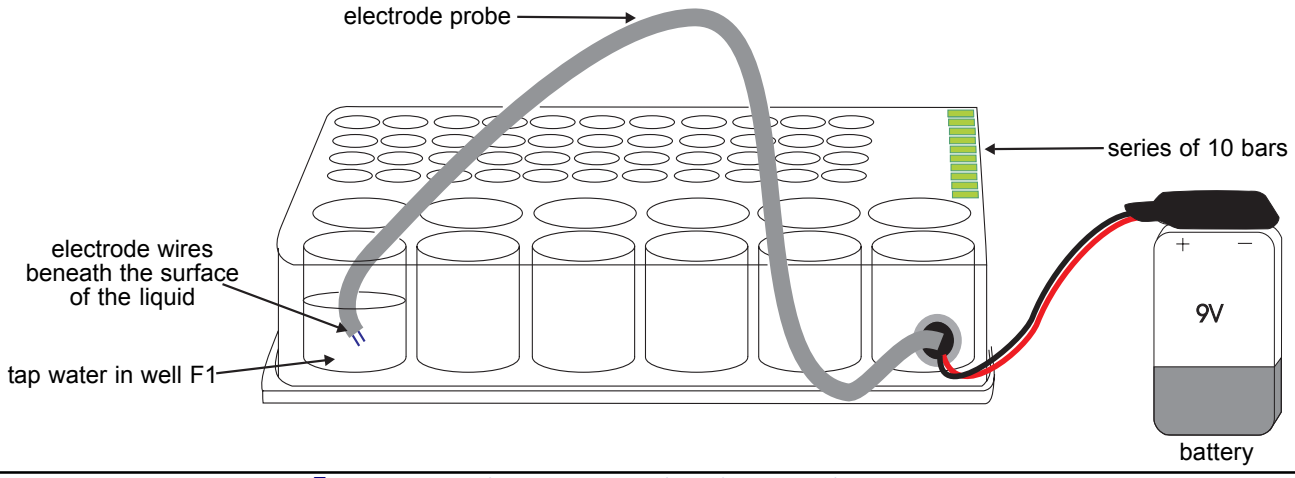
7. Use a fifth propette to fill two thirds of well F5 with cyclohexene (C_6H_{10}(l)).

CAUTION! **Close the bottle of cyclohexene as soon as you have finished dispensing it. The fumes are poisonous!**

8. Use a sixth propette to fill two thirds of well F6 with ethanol (C_2H_5OH(l)).

CAUTION! **Close the bottle of ethanol as soon as you have finished dispensing it. The fumes are poisonous!**

9. Squeeze all of the water out of the propette used to dispense the deionised water. Use this propette to fill two thirds of well E6 with glycerine ($HOCH_2CH(OH)CH_2OH$(l)).
10. Carefully immerse the electrodes in the centre of the tap water in well F1. Make sure that the electrodes at the end of the probe are beneath the surface of the water, but do not push the electrodes against the bottom of the well. (See the diagram below.) Wait a few seconds and then observe the number of bars that light up. (*See Question 1*)
11. Remove the electrodes from the solution and rinse the electrodes with deionised water. Allow the waste from the rinsing to fall into the paper cup. Dry the electrodes carefully with paper towel.
12. Immerse the clean, electrodes into the centre of the distilled water in well F2. Wait a few seconds and observe the number of lit bars. (*See Question 1*)
13. Remove the electrodes from the solution and rinse and dry them carefully. Repeat step 12 with the deionised water, cyclohexane and cyclohexene in wells F3, F4 and F5 respectively. Remember to dry the electrodes between each measurement.
14. Repeat step 12 with the ethanol in F6 and the glycerine in well E6, but this time rinse the electrodes with deionised water and dry them between each measurement.



THE CONDUCTIVITY OF SOME LIQUIDS

QUESTIONS

Q1. Prepare a table like Table 1 below and record your observations there.

TABLE 1: THE CONDUCTIVITY OF SOME LIQUIDS USING THE BAR LED CONDUCTIVITY INDICATOR

LIQUID TESTED	CONDUCTIVITY/NUMBER OF BARS GLOWING
Tap water ($H_2O(l)$)	
Distilled water ($H_2O(l)$)	
Deionised water ($H_2O(l)$)	
$C_6H_{12}(l)$	
$C_6H_{10}(l)$	
$C_2H_5OH(l)$	
$HOCH_2CH(OH)CH_2OH(l)$	

Q2. Which liquid/s tested are electrical conductors?

Q3. Why do the three samples of water have different conductivities?

Q4. Why do the pure liquids not conduct an electric current?

THE EFFECT OF ELECTROLYTE CONCENTRATION ON CONDUCTIVITY

REQUIREMENTS

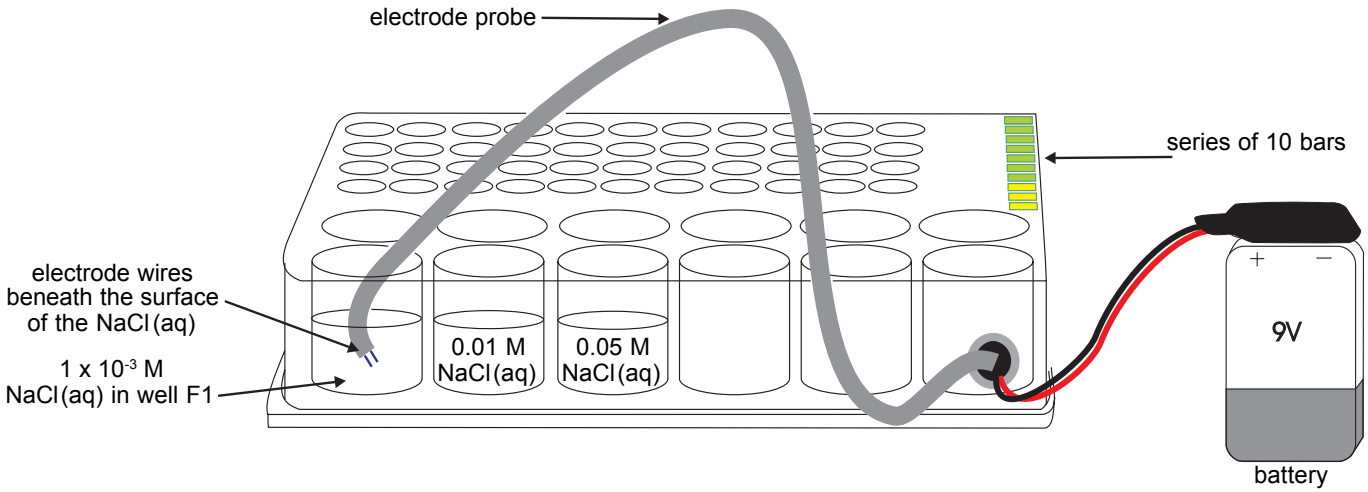
Apparatus: 1 x bar LED conductivity indicator; 1 x 9 V battery; 1 x comboplate®; 3 x thin stemmed propettes; Paper towel.

Chemicals: 1 x 10^{-3} M sodium chloride solution (NaCl(aq)); 0.01 M sodium chloride solution (NaCl(aq)); 0.05 M sodium chloride solution (NaCl(aq)); Deionised water.

Note **It is extremely important not to leave the electrodes in the solution for more than a few seconds at a time. If the electrodes are left in the solution, electrolysis may occur and affect the conductivity measured. If you see bubbling around the electrodes, immediately remove the probe from the solution.**

PROCEDURE

1. Connect the bar LED conductivity indicator to the 9V battery by means of the battery clip attached to the connecting wires of the indicator.
2. Use a clean, dry propette to fill two thirds of well F1 with 1 x 10^{-3} M sodium chloride solution (NaCl(aq)).
3. Use a second propette to fill two thirds of well F2 with 0.01 M NaCl(aq).
4. Use a third propette to fill two thirds of well F3 with 0.05 M NaCl(aq).
5. Carefully immerse the electrodes in the centre of the 1x10^{-3} M NaCl(aq) in well F1. Make sure that the electrodes at the end of the electrode probe are beneath the surface of the solution, but do not push the electrodes against the bottom of the well. (See the diagram below.) Wait a few seconds and then observe the number of bars that light up. (*See Question 1*)
6. Remove the electrodes from the solution in well F1 and immerse the electrodes in the centre of the 0.01 M NaCl(aq) in well F2. Do not rinse the electrodes yet.
7. Wait a few seconds and observe the number of lit bars. (*See Question 1*)
8. Remove the electrodes from the solution in well F2 and immerse the electrodes in the centre of the 0.05 M NaCl(aq) in well F3. Wait a few seconds and observe the number of lit bars. (*See Question 1*)
9. Remove the electrodes from the solution in well F3. Rinse the electrodes with deionised water and dry them gently with paper towel.



THE EFFECT OF ELECTROLYTE CONCENTRATION ON CONDUCTIVITY

QUESTIONS

Q1. Prepare a table like Table 1 below and record your observations there.

TABLE 1: THE EFFECT OF ELECTROLYTE CONCENTRATION ON CONDUCTIVITY

CONCENTRATION OF NaCl(aq) TESTED/ M	CONDUCTIVITY/NUMBER OF BARS GLOWING
1×10^{-3}	
0.01	
0.05	

Q2. What happens to the electrical conductivity of NaCl(aq) as its concentration is increased? Explain your answer.

Q3. Make a general statement about the relationship between conductivity and electrolyte concentration.

USING CONDUCTIVITY TO DISTINGUISH BETWEEN STRONG AND WEAK ACIDS AND BASES

REQUIREMENTS

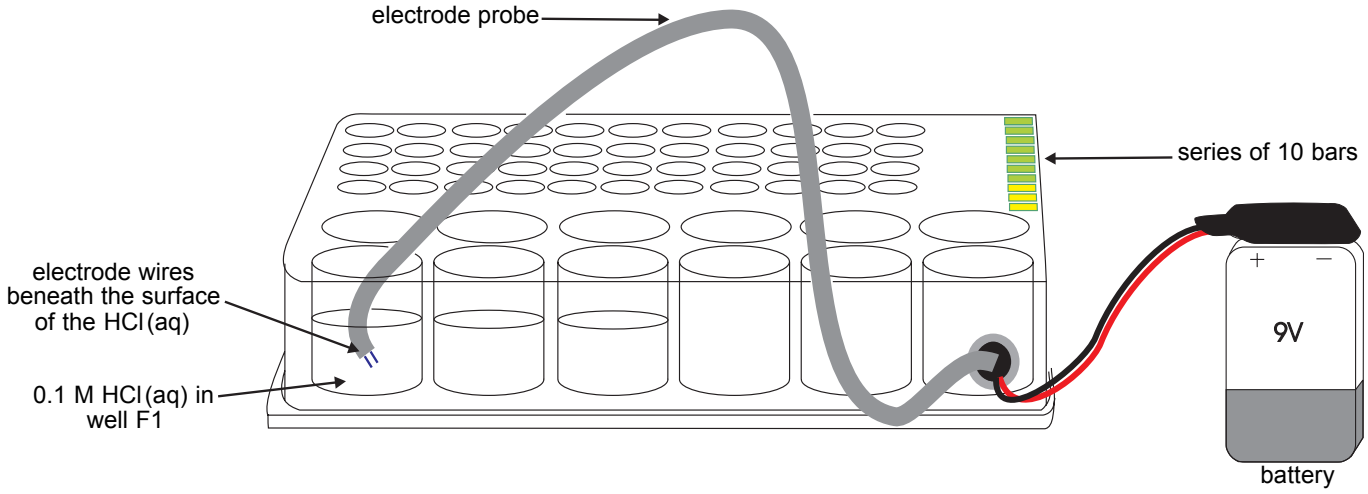
Apparatus: 1 x bar LED conductivity indicator; 1 x 9 V battery; 1 x comboplate®; 6 x thin stemmed propettes; Paper towel; 1 x paper cup.

Chemicals: 0.1 M hydrochloric acid (HCl(aq)); 0.1 M acetic acid ($CH_3COOH(aq)$); 1 M acetic acid ($CH_3COOH(aq)$); 0.1 M sodium hydroxide solution (NaOH(aq)); 0.1 M ammonia solution ($NH_3(aq)$); 1.0 M ammonia solution ($NH_3(aq)$); Deionised water.

Note **It is extremely important not to leave the electrodes in the solution for more than a few seconds at a time. If the electrodes are left in the solution, electrolysis may occur and affect the conductivity measured. If you see bubbling around the electrodes, immediately remove the probe from the solution.**

PROCEDURE

1. Connect the bar LED conductivity indicator to the 9V battery by means of the battery clip attached to the connecting wires of the indicator.
2. Use a clean, dry propette to fill two thirds of well F1 with 0.1 M hydrochloric acid (HCl(aq)).
3. Use a second propette to fill two thirds of well F2 with 0.1 M acetic acid ($CH_3COOH(aq)$).Use a third propette to fill two thirds of well F3 with 1 M acetic acid ($CH_3COOH(aq)$).
4. Use a fourth propette to fill two thirds of well F4 with 0.1 M sodium hydroxide solution (NaOH(aq)).
5. Use a fifth propette to fill two thirds of well F5 with 0.1 M ammonia solution ($NH_3(aq)$).
6. Use the last propette to fill two thirds of well F6 with 1 M ammonia solution ($NH_3(aq)$).
7. Carefully immerse the electrodes in the centre of the 0.1 M HCl(aq) in well F1. Make sure that the electrodes at the end of the electrode probe are beneath the surface of the solution, but do not push the electrodes against the bottom of the well. Wait a few seconds and then observe the number of lit bars. (*See Question 1*)
8. Remove the electrodes from the solution in well F1 and rinse the electrodes with a little deionised water. Allow the waste from the rinsing to fall into the paper cup. Dry the electrodes gently with paper towel.
9. Immerse the clean, dry electrodes in the centre of the 0.1 M $CH_3COOH(aq)$ in well F2. Wait a few seconds and observe the number of lit bars. (*See Question 1*)
10. Remove the electrodes from F2 and immerse the electrodes in the centre of the 1 M $CH_3COOH(aq)$ in well F3 without rinsing.
11. Observe the number of lit bars after a few seconds. (*See Question 1*) Rinse the electrodes with deionised water and dry with paper towel.
12. Immerse the clean, dry electrodes into the 0.1 M NaOH(aq) in well F4. Wait a few seconds and observe the number of lit bars (*See Question 1*) .
13. Remove the electrode probe, rinse the electrodes with deionised water and dry with paper towel.
14. Measure the conductivity of the 0.1 M $NH_3(aq)$ by immersing the electrodes in the centre of the solution in well F5. Observe the number of lit bars after a few seconds. (*See Question 1*)
15. Remove the electrode probe from well F5 and immerse the electrodes in the centre of the 1 M $NH_3(aq)$ in well F6 without rinsing. Observe the number of lit bars after a few seconds. (*See Question 1*)
16. Rinse and dry the electrodes as before.



USING CONDUCTIVITY TO DISTINGUISH BETWEEN STRONG AND WEAK ACIDS AND BASES

QUESTIONS

Q1. Prepare a table like Table 1 below and record your observations there.

TABLE 1: CONDUCTIVITY OF SOME STRONG AND WEAK ACIDS AND BASES

ACID/BASE	CONDUCTIVITY/NUMBER OF BARS GLOWING
0.1 M HCl(aq)	
0.1 M CH_3COOH(aq)	
1 M CH_3COOH(aq)	
0.1 M NaOH(aq)	
0.1 M NH_3(aq)	
1 M NH_3(aq)	

Q2. Which acid conducts electricity better, the 0.1 M HCl(aq) or the 0.1 M CH_3COOH(aq)?

Q3. Which base is the better electrical conductor, 0.1 M NaOH(aq) or 0.1 M NH_3(aq)?

Q4. A solution conducts an electric current because it contains mobile particles (ions) that carry charge. The greater the concentration of ions in solution, the higher the solution conductivity. Since one molecule of HC@ and one molecule of CH_3COOH can each yield one negative and one positive ion in solution and their solutions are identical in concentration, why do they have such different conductivities?

Q5. Based on your answer to Question 4, which of the acids is weak and which is strong?

Q6. What further evidence is there from the experiment to support your answer to Question 5?

Q7. Which of the bases tested is stronger, NaOH or NH_3? Explain your answer.

USING CONDUCTIVITY TO DISTINGUISH BETWEEN COMPLETELY DISSOCIATED AND PARTIALLY DISSOCIATED SALTS

REQUIREMENTS

Apparatus: 1 x bar LED conductivity indicator; 1 x 9 V battery; 1 x comboplate®; 2 x thin stemmed propettes; Paper towel; 1 x paper cup.

Chemicals: 0.1 M sodium chloride solution (NaCl(aq)); 0.1 M mercury(II) chloride solution ($HgCl_2$(aq)); Deionised water.

Note **It is extremely important not to leave the electrodes in the solution for more than a few seconds at a time. If the electrodes are left in the solution, electrolysis may occur and affect the conductivity measured. If you see bubbling around the electrodes, immediately remove the probe from the solution. Mercury(II) chloride rapidly corrodes the electrodes. Remove the probe promptly from the solution.**

PROCEDURE

1. Connect the bar LED conductivity indicator to the 9V battery by means of the battery clip attached to the connecting wires of the indicator.

2. Use a clean, dry propette to fill two thirds of well F1 with 0.1 M sodium chloride solution (NaCl(aq)).

3. Use a second propette to fill two thirds of well F2 with the 0.1 M mercury(II) chloride solution ($HgCl_2$(aq)).

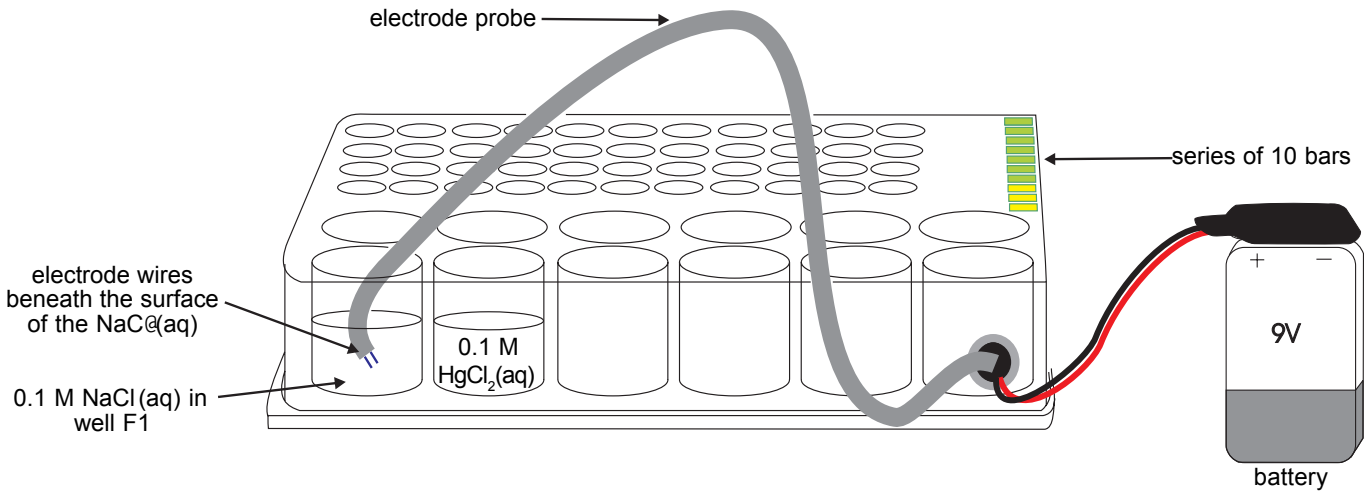
4. Carefully immerse the electrodes in the centre of the 0.1 M NaCl(aq) in well F1. Make sure that the electrodes at the end of the probe are beneath the surface of the solution, but do not push the electrodes against the bottom of the well. Wait a few seconds and then observe the number of lit bars. (*See Question 1*)

5. Remove the electrodes from the solution in well F1 and rinse the electrodes with a little deionised water. Allow the waste from the rinsing to fall into the paper cup. Dry the electrodes gently with paper towel.

6. Immerse the clean, dry electrodes in the centre of the 0.1 M $HgCl_2$(aq) in well F2. Wait a few seconds and observe the number of lit bars. (*See Question 1*)

Note **Mercury(II) chloride rapidly corrodes the electrodes. Remove the probe promptly from the solution.**

7. Remove the electrodes, rinse them with deionised water and dry with paper towel.



USING CONDUCTIVITY TO DISTINGUISH BETWEEN COMPLETELY DISSOCIATED AND PARTIALLY DISSOCIATED SALTS

QUESTIONS

Q1. Prepare a table like Table 1 below and record your observations there.

TABLE 1: THE CONDUCTIVITY OF COMPLETELY DISSOCIATED AND PARTIALLY DISSOCIATED SALTS

SOLUTION	CONDUCTIVITY/NUMBER OF BARS GLOWING
0.1 M NaCl(aq)	
0.1 M $HgCl_2$(aq)	

Q2. Which salt solution is the better electrolyte?

Q3. When a crystal of NaCl(s) dissolves in water, the ionic bonds are broken forming Na^+(aq) and Cl^-(aq) ions: NaCl(s) $\rightarrow$ Na^+(aq) + Cl^-(aq). When a crystal of $HgCl_2$(s) is placed in water, $HgCl_2$(s) molecules mix with water molecules and some of them dissociate according to the equation:

$$\mathbf{HgCl_2(s) \rightleftharpoons HgCl^+(aq) + Cl^-(aq).}$$

Use this information to explain your answer to Question 2 and the conductivity results obtained.

ASSEMBLY AND USE OF THE MICROBURETTE IN MICROSCALE VOLUMETRIC ANALYSIS

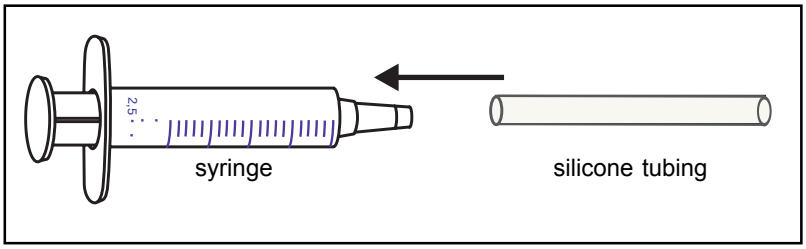
INTRODUCTORY NOTES

Assembling the Microburette

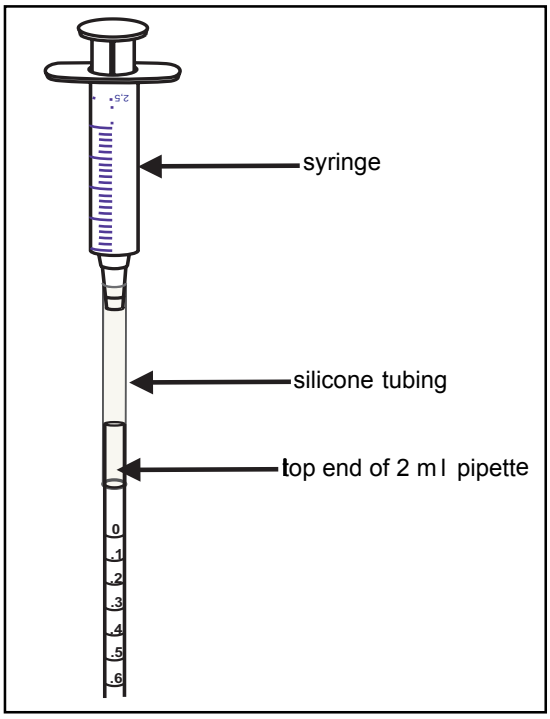
APPARATUS

- 2 x 2 ml plastic syringes
- 2 x 2 ml plastic pipettes graduated in 0.01 ml intervals
- 2 x plastic pipette tips
- 2 x silicone tubes (~ 4 cm in length)
- 2 x plastic microstands
- 1 x comboplate®
- 2 x propettes
- microspatulas

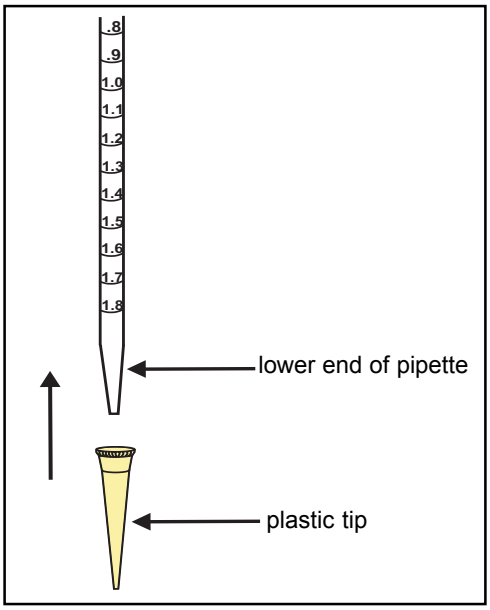
1. Attach one end of the silicone tubing to the 2 ml syringe by gently sliding the tubing over the nozzle of the syringe.



2. Connect the remaining end of the silicone tubing to the 2 ml pipette by similarly sliding the tubing over the top of the pipette.

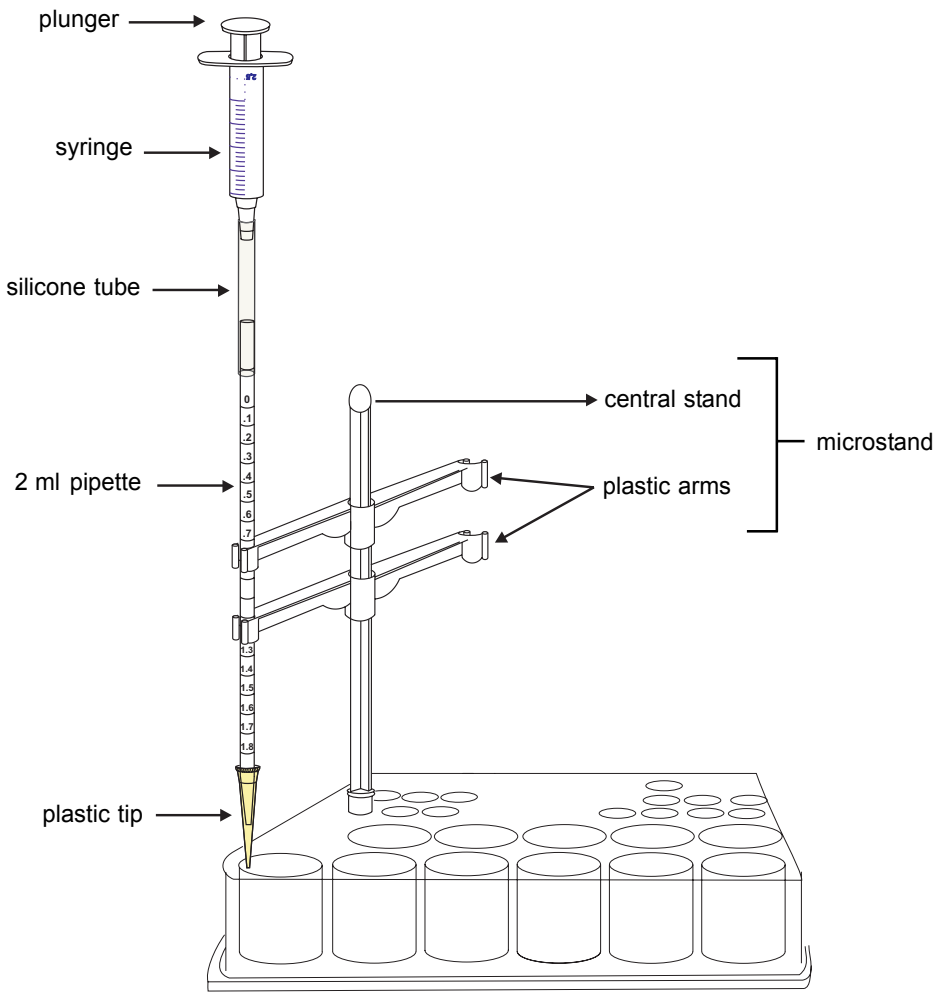


3. Place the plastic tip on the bottom, pointed end of the pipette. Make sure that the tip is secure to prevent it from falling off during the titration procedure.



4. Assemble the microstand by placing two plastic arms onto one of the central retorts. Clamp the now-assembled microburette in an upright position by clipping the pipette into each arm of the microstand.

5. Push the microstand into one of the small wells in the comboplate®. Adjust the position of the microburette by sliding the pipette up or down the arms of the microstand.



comboplate

Operating the Microburette

The following instructions are intended as a practice session for operating the microburette. Water is used to represent the titrant solution. For this reason, excess water in the microburette can be returned to the water container. However, remember that when an actual titration is performed excess solution should never be returned to the original titrant container, but discarded as waste.

REQUIREMENTS

- 1 x microburette
- 1 x waste container
- 1 x comboplate®
- 1 x microspatula
- water

A. Rinsing the microburette

1. Slide down the plunger of the syringe until it is all the way inside the syringe. The plunger should move easily up and down inside the syringe. If it is tight, you may need to pump the plunger inside the barrel of the syringe until it slides smoothly. Alternatively, the plunger can be replaced with another that slides easily.
2. Hold the container of water (or titrant solution) under the microburette so that the plastic tip is completely immersed in the water. This will prevent air bubbles being drawn into the microburette from the surface of the water.
3. Gently slide the plunger upwards, allowing about 0,2 to 0,3 ml of water to enter the microburette. Remove the container of water.
4. Slide the plunger of the syringe several times slowly up and down without forcing the water out of the microburette. The water will move up and down, rinsing the inside of the microburette. Discard the rinse solution into a large well of the comboplate®.
5. Repeat the rinsing step another two times.

B. Titrating with the microburette

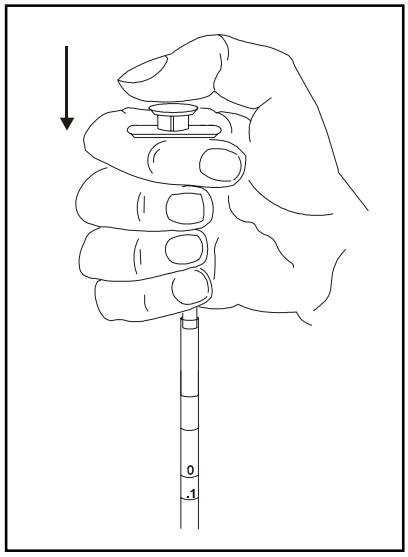
1. Immerse the end of the microburette as before into the water (or titrant solution). Gently slide the syringe plunger upwards to fill the burette up to the 1,00 ml level. **Do not pull the plunger up too quickly as this will cause the titrant solution to fill the entire microburette, including the silicone tubing and syringe.**
2. An air bubble may form at the end inside the plastic tip. This can be removed by forcing all of the titrant solution out of the microburette, and then refilling the microburette to the desired level. If the bubble persists, you may need to adjust or replace the plastic tip.
3. Read the bottom of the meniscus level and record the volume of the titrant solution in the microburette. Enter this as the initial volume in Table 1.

   You may place a piece of white paper behind the microburette to make reading of the meniscus level easier.

TABLE 1

Titrant volume/ml	Titration 1	Titration 2	Titration 3
Final volume : Initial volume :	_____ _____	_____ _____	_____ _____
Volume dispensed:	_____	_____	_____

4. To titrate, gently push the syringe plunger down until one drop of titrant has been dispensed. **Do not force the plunger down hard as this will cause a large volume of titrant to be dispensed. When performing an actual titration, this may lead to overshooting the end point.** Repeat this step until a total of five drops has been dispensed.



5. Record the volume of titrant remaining in the microburette by reading the bottom of the menicus level. Enter this as the final volume in Table 1 and calculate the volume of titrant dispensed.

6. Practise the titration technique by repeating steps 1 - 5 twice more. Enter the results in Table 1.

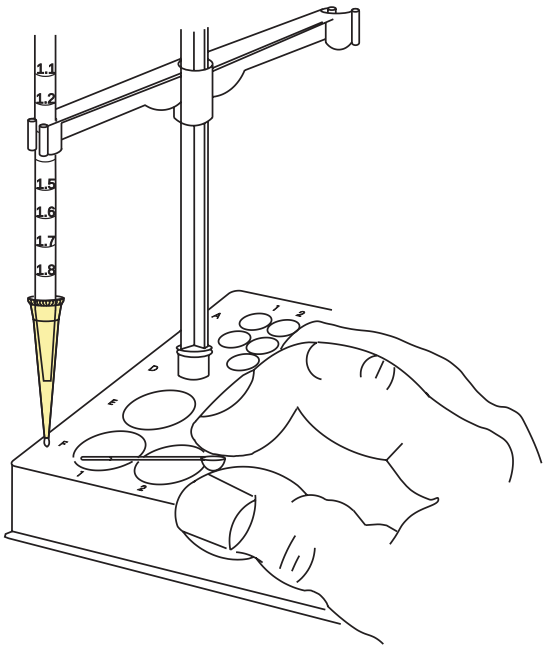
C. Dispensing fractional volumes using the microburette

When performing an actual titration, it may happen that the end point is reached before an entire drop of titrant is dispensed. In other words, less than one drop is needed to complete the titration. Fractional drops can be delivered using the technique below.

1. Push down very gently on the syringe plunger so that a drop of titrant begins to form at the end of the plastic tip, but is not released into the analyte solution.

   This step may require special attention and practise as it involves fine control and manipulation of the syringe.

2. Touch the suspended droplet with the narrow end of the plastic microspatula. The droplet will adhere to the microspatula.



A CONDUCTOMETRIC TITRATION

THE DETERMINATION OF THE CONCENTRATION OF A ~ 0.01 M BARIUM HYDROXIDE SOLUTION, BY MEASURING THE CHANGE IN SOLUTION CONDUCTIVITY DURING A PRECIPITATION REACTION WITH 0.01 M SULPHURIC ACID

REQUIREMENTS

Apparatus: 1 x propette; 1 x microspatula; 1 x retort stand; 2 x plastic arms; 2 x 2ml graduated plastic pipettes; 1 x pipette tip; 1 silicone tube; 1 x 2 ml syringe; 1 x bar LED conductivity indicator; 1 x 9V battery; paper towel.

Chemicals: Standard sulphuric acid ($H_2SO_4(aq)$) [0.01 M]; barium hydroxide solution ($Ba(OH)_2(aq)$) [~ 0.01 M]; Distilled water.

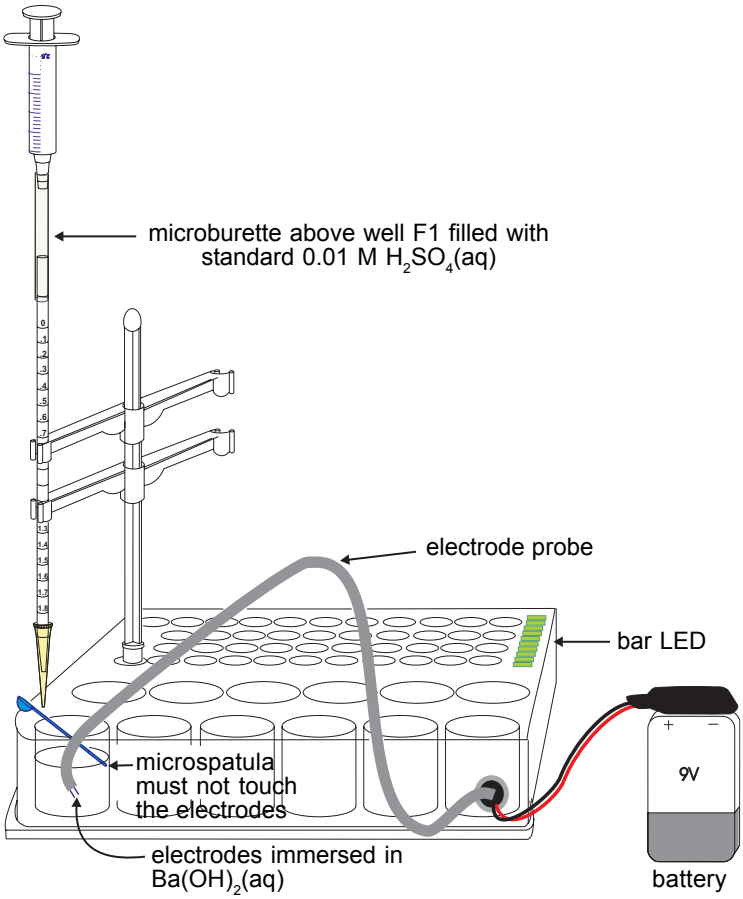
Note

It is very important to remove the electrode probe from the solution. The bar LED conductivity indicator has a DC (Direct Current) circuit. If the probe is left in the reaction solution, electrolysis will occur and affect the conductivity measured. If any droplets of solution remain on the electrode wires, the same problem will occur. It is therefore also important to transfer any solution from the wires into the bulk of the solution using the microspatula, after recording the conductivity measured.

Make sure that you replace the lid of the reagent bottle containing the barium hydroxide, otherwise carbon dioxide from the air will dissolve in the solution while you are performing the titration. This will alter the concentration of the barium hydroxide so that the results of successive titrations differ.

PROCEDURE

1. The $H_2SO_4(aq)$ should be standardised prior to the experiment. Write down the exact $H_2SO_4(aq)$ concentration which appears on the reagent bottle. *(See Question 1)*
2. Assemble the microburette as described in the introductory notes. Push the plastic microstand into well D2 of the bar LED conductivity indicator. Orient the pairs of arms on the central stem of the microstand so that one arm of each pair is directly above well F1. Clip the assembled microburette into each arm of the microstand above well F1.
3. Rinse the other 2 ml pipette in the kit with the barium hydroxide solution. Do not pipette the solution using your mouth. Copy the design of the microburette by attaching the plastic syringe to the top of the 2 m@pipette using silicone tubing. Place a plastic tip at the end of the pipette. Rinse the pipette as described in the introductory notes for the microburette. Repeat the process twice more.
4. Fill the rinsed pipette with exactly 1,00 ml of the $Ba(OH)_2(aq)$. Dispense all of this solution into well F1 of the comboplate® .
5. Rinse the microburette at least two times with the 0.01 M $H_2SO_4(aq)$, as described in the introductory notes.
6. Fill the microburette with the $H_2SO_4(aq)$ to the 0,00 ml level.
7. Connect the bar LED conductivity indicator to the 9V battery using the battery clip. (See the diagram)
8. Immerse the electrodes of the electrode probe in the centre of the barium hydroxide solution in well F1. Make sure that the electrodes are beneath the surface of the solution, but do not push them against the bottom of the well. Wait a few seconds before recording the number of bars lit, as there may be some fluctuation in the conductivity when the electrodes are first placed into the solution. *(See Question 2)*



9. Remove the electrode probe from the solution. If there are any droplet/s of $Ba(OH)_2(aq)$ remaining on the electrodes, touch the probe against the narrow edge of the microspatula. Use the microspatula to transfer the droplet/s into the solution in the well. Leave the microspatula in the well during the titration.
10. Position the microburette on the comboplate® so that the tip of the microburette is above well F1. Do not place the microburette too close to well F1 as the plastic microspatula may knock against it during stirring of the solution in the well. This may cause drops of the solution to splash out of the well.
11. Push down gently on the syringe plunger as described in the introductory notes and dispense 0,1 ml $H_2SO_4(aq)$ into well F1. This is best done by adding the $H_2SO_4(aq)$ dropwise until 0,1 ml has been dispensed. Stir the solution in well F1 with the plastic microspatula, being careful not to spill any solution out of the well.
12. Immerse the electrodes of the probe in the centre of the solution as before. Wait a few seconds before recording the number of bars lit. *(See Question 2)*

Note **You must record the exact volume of $H_2SO_4(aq)$ that was added from the microburette eg. if you added 0,12 ml instead of 0,10 ml of the acid, you must record this in Table 1 because the exact volumes are required to draw an accurate graph at the end of the titration. If you need to add a very small volume of the acid, then use the end of the microspatula to add fractions of a drop as described in the introductory notes.**

13. Remove the electrode probe from the solution. Touch the electrodes against the microspatula to transfer any droplets of solution into the well as before.
14. Continue to add $H_2SO_4(aq)$ from the microburette 0,1 ml at a time. Stir the solution with the microspatula already in well F1 after each 0,1 ml added. Measure the conductivity after each 0,1 ml added, by recording the number of bars lit a few seconds after immersing the electrodes.
15. Stop the titration before 1,8 ml of $H_2SO_4(aq)$ has been added. (It is usually sufficient to terminate the titration at about 1,5 ml of sulphuric acid added.)
16. Rinse the electrode wires with distilled or deionised water, and dry them gently with paper towel before beginning the next titration.
17. Refill the microburette with $H_2SO_4(aq)$ to the 0,00 ml level. Fill the pipette with another 1,00 ml of the $Ba(OH)_2(aq)$. Dispense all of this solution into well F2 of the comboplate® .
18. Record the conductivity of the barium hydroxide solution as before. Remember to remove the probe from the solution and transfer any droplets of solution from the electrode wires into the well with the microspatula.
19. Position the microburette above well F2 by moving the plastic microstand to another small well in the D row of the comboplate® .
20. Add the $H_2SO_4(aq)$ 0,1 ml at a time. Stir the solution in well F2 and record the conductivity after each 0,1 ml added, as you did for the first titration.
21. Repeat the titration in well F3. *(See Question 2)*

A CONDUCTOMETRIC TITRATION

THE DETERMINATION OF THE CONCENTRATION OF A ~ 0.01 M BARIUM HYDROXIDE SOLUTION, BY MEASURING THE CHANGE IN SOLUTION CONDUCTIVITY DURING A PRECIPITATION REACTION WITH 0.01 M SULPHURIC ACID

QUESTIONS

Q1. Write down the exact $H_2SO_4(aq)$ concentration which appears on the reagent bottle.

Q2. Prepare a table like Table 1 below and record your observations in the table. Tabulate your result for titrations 1, 2 and 3.

TABLE 1: Change in solution conductivity as 1.00 ml of $Ba(OH)_2(aq)$ is titrated with 0.01 M $H_2SO_4(aq)$

titration number	1		2		3	
Volume $H_2SO_4(aq)$ /ml	Exact volume of $H_2SO_4(aq)$ added /ml	Conductivity /no. of bars lit	Exact volume of $H_2SO_4(aq)$ added /ml	Conductivity /no. of bars lit	Exact volume of $H_2SO_4(aq)$ added /ml	Conductivity /no. of bars lit
0.00						
0.10						
0.20						
0.30						
0.40						
0.50						
0.60						
0.70						
0.80						
0.90						
1.00						
1.10						
1.20						
1.30						
1.40						
1.50						
1.60						

Q3. For each titration, prepare a graph of the conductivity/number of bars lit (Y axis) versus the volume of $H_2SO_4(aq)$ (X axis). Plot the results obtained in Table 1 on the graph of each titration.

The scientific method used for finding the concentration of $Ba(OH)_2(aq)$ with graphs like the one which you have prepared, is to draw the best straight line through the set of points showing a negative slope and another best straight line through the set of points which display a positive slope. Therefore, draw the best straight line through the set of points between 0.00 ml and the volume of sulphuric acid at which the minimum number of bars was lit. Now draw the best straight line through the set of points between this volume that gave the lowest conductivity, and the volume of sulphuric acid at which you took your final measurement. Where the two lines intersect is the true minimum point on the curve (i.e. where the conductivity of the reaction solution was at its lowest.)

Q4. Drop a perpendicular from this minimum point onto the X axis of each graph and record the volume of $H_2SO_4(aq)$ where the perpendicular touches the axis.

Q5. Write down the balanced chemical equation of the reaction between sulphuric acid and barium hydroxide.

Q6. Use this equation and the volume of $H_2SO_4(aq)$ at minimum conductivity obtained from each of the three graphs, to calculate the concentration of $Ba(OH)_2(aq)$. Do not average the acid volume obtained from the three graphs; calculate the concentration of $Ba(OH)_2(aq)$ from each set of titration data.

Q7. What change did you notice in the appearance of the reaction solution as sulphuric acid was added to the barium hydroxide?

Q8. Explain this change in appearance of the reaction solution. (Hint: look at the chemical equation you used in your calculations.)

Q9. What changes in the conductivity (number of bars lit) of the reaction solution did you observe whilst performing each titration?

Q10. Explain the conductivity changes in terms of the reaction between $H_2SO_4(aq)$ and $Ba(OH)_2(aq)$.

Q11. If the conductivity indicator was extremely sensitive, what conductivity would you expect to measure at the end point of the titration?

Q12. How would you detect this conductivity?

Q13. Explain why you would get this conductivity.

Q14. What metals/non-metals are suitable for electrodes that measure conductivity? Which metals are unsuitable for electrodes?

Q15. What is the effect of the distance between the electrodes on the number of lit bars?

POTENTIOMETRIC TITRATION OF AN ACID AND A BASE

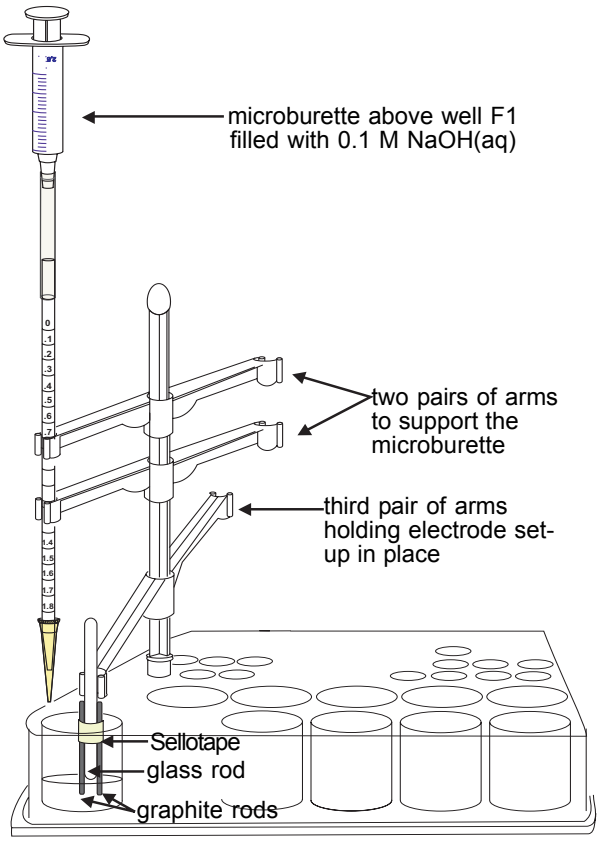
REQUIREMENTS

Apparatus: 2 x 2 ml syringes; 2 x 2 ml plastic pipettes (graduated at 0.01 ml intervals) ; 2 x plastic pipette tips ; 2 x silicone tubes (5 cm) ; 1 x plastic retort stand ; 3 x plastic arms ; 3 x propettes ; 2 x carbon /graphite rods; 1 x glass rod; 1 x piece of Sellotape; 1 x multimeter ; connecting wires for the multimeter ; 1 x comboplate®.

Chemicals: Sodium hydroxide solution (NaOH(aq)) [0.1 M]; Hydrochloric acid (HCl(aq)) [0.1 M]; Sulphuric acid (H_2SO_4(aq)) [2.0 M]; Potassium permanganate powder ($KMnO_4$(s)); Universal Indicator.

PROCEDURE

1. Activate one carbon rod as follows: Dispense sulphuric acid [2.0 M] into well F6 until it is 3/4 full. Add one microspatula of potassium permanganate to well F1 and mix with the other end of the microspatula. Take one of the carbon/graphite rods and place it in this acidified potassium permanganate solution for 10 minutes. Remove from the solution and rinse it thoroughly with water. Place it on one side.
2. Assemble the microburette and rinse it twice with sodium hydroxide solution (NaOH(aq)) [0.1 M], as described in the introductory notes. Push the plastic retort stand into well D1 of the comboplate®. Place all 3 plastic arms on the retort stand. Orient the top 2 plastic arms on the central stem of the retort stand so that one arm of each pair is directly above well F1. Fill the microburette with the sodium hydroxide solution (NaOH(aq)) [0.1 M] to the 0.00 ml level exactly. Clip the assembled microburette into both of the top plastic arms of the microstand above well F1.
3. Hold the glass rod in one hand. Place the 2 graphite rods (the one activated and the other non-activated) on either side of the glass rod, such that each graphite rod is protruding 1 cm from the glass rod. Hold them in place with the piece of Sellotape. Attach a single coated copper wire to each of the graphite electrodes. Now clamp the glass rod to the third plastic arm and orient it so that the assembly is placed in well F1. See from the side that the electrodes are not touching the bottom of the well. (See the diagram.)



4. Attach the other end of each coated copper wire to the multimeter. The multimeter should be set at 2000 mV. Rinse another 2 ml pipette with the 0.1 M hydrochloric acid (HCl(aq)). Do not pipette the solution using your mouth. Copy the design of the microburette by attaching the syringe to the top of the 2 ml pipette using silicone tubing. Place a plastic tip at the end of the pipette. Rinse the pipette as described in the introductory notes for the microburette. Repeat the process once more.
5. Fill the rinsed pipette with exactly 0.5 ml of 0.1 M hydrochloric acid (HCl(aq)). Dispense all of this solution into well F1 of the comboplate®. Make sure that both the carbon electrodes are immersed in the HCl(aq). Repeat the process twice more, dispensing exactly 0.5 ml of the 0.1 M hydrochloric acid into wells F2 and F3. Using a clean propette, add 1 drop of universal indicator to well F1.
6. Take the reading on the multimeter. If the reading on the multimeter indicates a negative value, remove the wires from the carbon/graphite electrodes and reconnect them in the opposite direction. *(See Question 1).*
7. Push down gently on the syringe plunger as described in the introductory notes and dispense exactly 0.1 ml of NaOH(aq) into well F1. Look at the reading on the multimeter. Wait until the reading on the multimeter stabilises before recording it. *(See Question 1)*
8. Continue by dispensing 0.1 ml of NaOH(aq) each time and taking the reading and noting the colour of the indicator. This can be done until you have dispensed 0.7 ml of NaOH(aq) altogether. *(See Question 2)*
9. The titration in well F1 will give you an idea of when the end point is reached. Refill the microburette with the sodium hydroxide solution (NaOH(aq)) [0.1 M] to the 0.00 ml mark exactly. Move the retort stand and repeat the titration in well F2. For this titration start dispensing 0.02 ml quantities of NaOH(aq), 0.1 ml before the end point is reached. When you have dispensed 0.06 ml of NaOH altogether, start dispensing in 0.01 ml increments. Continue dispensing 0.01 ml of NaOH(aq),up to 0.06 ml after the end point is reached.
10. Repeat step 9 in well F3.

POTENTIOMETRIC TITRATION OF AN ACID AND A BASE

QUESTIONS

Q1. What is the reading (mV) on the multimeter ? Construct a Table like the one below, and enter the multimeter reading and the volume of NaOH(aq).

TABLE 1: Change in multimeter reading (mV) as HCl(aq) is titrated with NaOH(aq)

Volume NaOH(aq) /ml	MULTIMETER READING (mV)		
	TITRATION 1	TITRATION 2	TITRATION 3
0.000			

Q2. In Titration 1, at what volume of NaOH(aq) was the approximate end-point reached according to the colour change of the universal indicator?

Q3. Draw a graph of multimeter reading (mV) vs volume of NaOH(aq) (ml) by using the readings for either Titration 2 or 3.

Q4. What is the volume of NaOH(aq) at the end point of the titration ?

Q5. If the hydrochloric acid used was exactly 0.1000 M , what would be the concentration of the NaOH(aq) ?

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