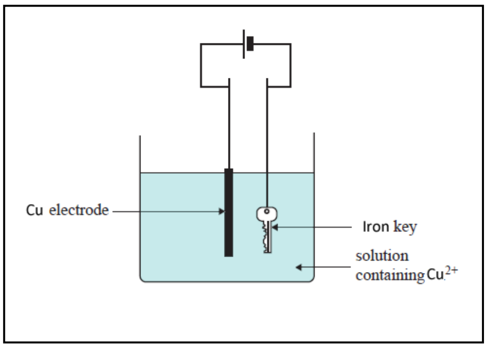
Experimental technique.

Revision 1

Electroplating an iron key with copper metal



Aim

To investigate whether Faraday's laws apply to the electroplating of a brass key with nickel

Procedure

The apparatus was set up as in the diagram above. The electrolytic cell was filled with the electrolyte solution provided, 0.10 M $CuSO_4$.

Step 1 – The iron key was sanded, weighed and placed in the solution, as shown above.

Step 2 – A current was applied for exactly 20.0 minutes. Both the current and voltage were measured once, when the power was turned on.

Step 3 – The key was removed from the solution, washed with acetone, allowed to dry and weighed to constant mass.

Steps 1–3 were repeated for two more keys .

Results

Three trials of the experiment were conducted as shown in the table below.

Trial	Initial mass of key (g)	Final mass of key (g)	Mass of copper deposit (g)	Current (A)	Voltage (V)
1	2.105	2.271	0.166	0.210	2.4
2	2.952	3.104	0.152	0.192	2.2
3	3.115	3.305	0.190	0.221	1.9

1) **The student wrote in their report**

Conclusion- Faraday's laws apply to the electroplating of an iron key with copper. Do you agree with this conclusion? Provide evidence to support your decision based on trial 1 and 2.

Results show limited consistency with Faraday's first law – mass of Cu deposited should be proportional to charge passed and mass of Cu deposited should be higher for a higher current, assuming the time is constant, which in this case it is.

Trials 1 and 2 reflect Faraday's first law – that is mass is proportional to charge.

For 1, m/current = 0.166/0.210 = 0.790

For 2, m/current = 0.152/0.192 = 0.792

For Trial 3, however – m/current = 0.190/0.221 = 0.860 – hence more trials are needed to confirm relationship.

Faraday's second Law: The amount of electricity, in coulombs, required to produce 1 mole of a substance is a simple whole number multiple of 96500. This was not tested and further investigations are required.

2) Consider trial 3 what mass of copper should have deposited on the key?
Step 1 – Calculate the theoretical amount of copper that should have deposited.
=> Calculate charge Q = I X t = 0.221 X 20.0 X 60 = 265.2
=> Calculate the mol of electrons 265.2 / 96500 = 0.00275
=> Calculate the theoretical mass of copper = 0.00275 X 63.5 = 0.175 g.

3) Evaluate the student's experimental design:

- identify and explain **one** strength of the experimental design

Any of the following but not limited to the ones mentioned below.

  - *Time was the same in all three trials. Less variables to consider,*
  - *Multiple trials were conducted. This makes for better verification of results to see if mass is proportional to current.*
  - *A copper anode is used. This makes for consistent Cu^{2+} concentration in the solution.*
  - *Weighing the plated key to constant mass. This ensures accurate measurement of deposited copper.*
  - *Sanding of the iron keys before weighing. This ensures the removal of all rust and impurities on the surface.*

- suggest **two** improvements or modifications that you would make to the experimental design and justify your suggestions

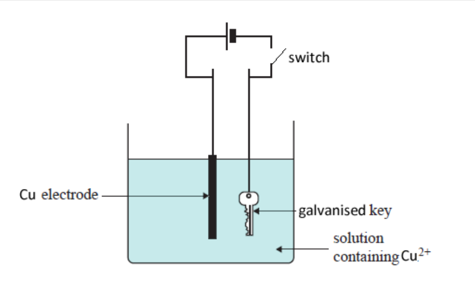
Any of the following but not limited to the ones mentioned below.

  - *Wash the sanded key before drying and weighing to constant mass. This ensures that all particles that result from sanding are removed from the surface of the key key.*
  - *A longer time was used to deliver the current. This would have resulted in greater mass of copper being deposited and hence reduced the percentage error when weighing the final platted key.*
  - *Identical keys should be used. This ensures the shape and surface area of the key are constant for each trial.*
  - *Steps taken to ensure that the current is monitored throughout the investigation and not just measured at the start. This will ensure that the current is relevant to the investigation and the results are valid.*
  - *Conduct more trials using different currents. This will allow a greater array of data from which to draw conclusions.*
  - *Ensure voltage is constant and not too high. High voltages enable side reactions to occur at the anode and cathode due to electrolysis of water.*

4) A student offered the following suggestion to an improvement or modification. "A fresh electrolyte solution should be used for every trial as the concentration of Cu^{2+} ions changes. Discuss how valid this modification is.

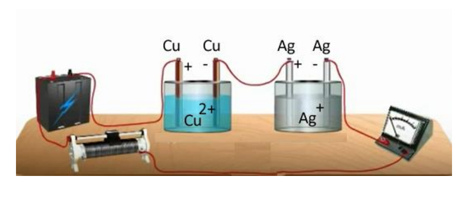
The fact that we have a copper anode that constantly supplies Cu^{2+} ions to the electrolyte means that the electrolyte concentration of Cu^{2+} remains constant. Replacing the electrolyte is not required.

5) Consider the electrolytic setup shown on the right. A galvanised iron key is to be plated with copper. The key is connected to the open circuit (switch is off) and immersed in the electrolyte. Five minutes later the switch is turned on and the current and voltage measured. Galvanised steel has a layer of zinc placed on its surface. How will this influence the ratio of mass / current obtained in the above investigation with a pure iron key. Explain your answer with reference to the electrochemical series.



The ratio would be greater. A greater amount of copper is deposited using a lower current.
The reason for this is, before the switch is turned on the Zn on the key will react spontaneously with the copper ions according to the following equation,
$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$.
Hence even before the switch is turned copper is being deposited onto the key.
As the key is turned on and current flows at the anode Cu^{2+} *ions will form while at the cathode Cu will be deposited.*

6) The experimental setup pictured on the right is used to verify Faraday's second Law. Two electrolytic cells are connected in series. A current is passed through each cell for 20 minutes. The mass of metal deposited on each cathode is then measured.



Faradays second law states, 'The amount of electricity, in coulombs, required to produce 1 mole of a substance is a simple whole number multiple of 96500. "

a) What are the dependent and independent variables?
The valency of each element is the independent variable. Cu is 2+ and Ag is +
Mass of each element deposited is the dependent variable.

b) Which of the following variables should be kept constant between the two electrolytic cells?
  i. The concentration of the copper and silver solutions
  ii. The shape and size of the electrodes.
  iii. The volume of the each solution
  iv. The depth to which each electrode is submerged in the solution.

All of the variables mentioned above should be kept constant.

c) Mention one other variable that is kept constant.
Current.

Multiple choice questions

The following information relates to questions 1-5

The percentage of iron in a rock sample of iron(III)oxide was determined by gravimetric analysis. Below is the procedure one student wrote in their log book.

Prior knowledge:

- iron(III) oxide is an insoluble in water
- iron(III) oxide is a basic oxide and dissolves in hot concentrated hydrochloric acid
- Fe^{3+} ions form insoluble $Fe(OH)_3$ in the presence of hydroxide ions
- upon heating $Fe(OH)_3$ decomposes to Fe_2O_3.

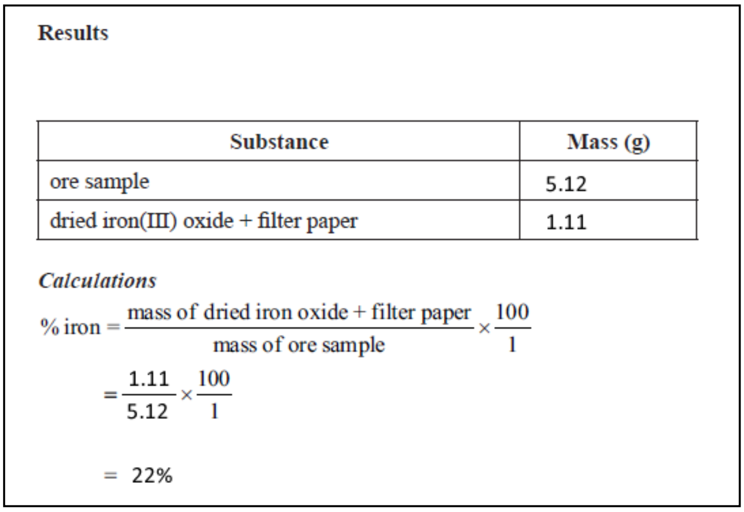
Experimental procedure

1. An electronic balance was zeroed and a sample of rock was weighed into a 500 mL beaker, which was then placed in a fume cupboard. We then added 40 mL of concentrated hydrochloric acid and warmed the solution over a hotplate to dissolve the rock. It was known that 40 mL of concentrated HCl would be enough to completely dissolve all the Fe_2O_3 *present in the sample.*

2. The content of the beaker was diluted by the addition of 200 mL of distilled water. To the beaker we then slowly added 5 M sodium hydroxide solution until no more precipitate was seen to form.

3. The contents of the beaker were then filtered and the precipitate collected. The precipitate and filter paper were then transferred to a crucible, which was heated to constant mass.

4. The crucible and its contents were allowed to cool over several ours at room temperature, and the paper and solid were removed from it and weighed.



Results

Substance	Mass (g)
ore sample	5.12
dried iron(III) oxide + filter paper	1.11

Calculations

$$\%\ \text{iron} = \frac{\text{mass of dried iron oxide + filter paper}}{\text{mass of ore sample}} \times \frac{100}{1}$$

$$= \frac{1.11}{5.12} \times \frac{100}{1}$$

$$= 22\%$$

Conclusion- We found that the percentage composition of iron in the rock is 22%

1) Which of the following should most likely be done before step 1 and what are the consequences if this is not done?

a) Wash the rock to remove any impurities of other elements, if this is not done the percentage of Fe in the rock would be lower than its true value.

[✓ b)] Crush the rock to allow all the Fe_2O_3 to react, if this is not done the percentage of Fe in the rock would be lower than its true value.

c) Heat the rock to allow for a faster reaction in step 1, if this is not done the percentage of Fe in the rock would be lower than its true value.

d) Wash the rock with concentrated HCl solution, if this is not done the percentage of Fe in the rock would be lower than its true value.

2) Which one of the following should be done before step 2?

a) Add 80 mL of concentrated HCl to dissolve all the Fe_2O_3 present.

b) Accurately weigh the beaker and its contents

c) Allow the beaker to stand for several minutes to allow the precipitate to settle to the bottom of the beaker.

[✓ d)] The contents of the 500 mL beaker should be filtered to remove any undissolved rock particles.

3) Which of the following is a critical error of the experimental procedure?

a) The mass of the crucible must be known before step 3

[✓ b)] The mass of the dry filter paper should be known before step 3

c) There is no need to heat the crucible and its contents to constant mass.

d) The volume of NaOH added at step 2 should be accurately known.

4) Which of the following options **best** explains the accuracy of the final result and why?

a) It is not accurate as it is given to 2 significant figures and it should by given to 3 significant figures.

b) It is very accurate as care was taken to remove all the Fe present and weigh it accurately using an electronic balance.

[✓ c)] It is highly inaccurate as the filter paper has not being accounted for in the final mass of Fe.

d) It is highly inaccurate as the mass of the crucible has not been taken into account.

5) On the right is the section on errors that was given by another group of students. Which of the following comments is true?

a) Error 1) is a random error.

[✓ b)] Error 2) is a human error and should not be included in the report.

c) Both 1) and 2) are random errors and should not be included in the report.

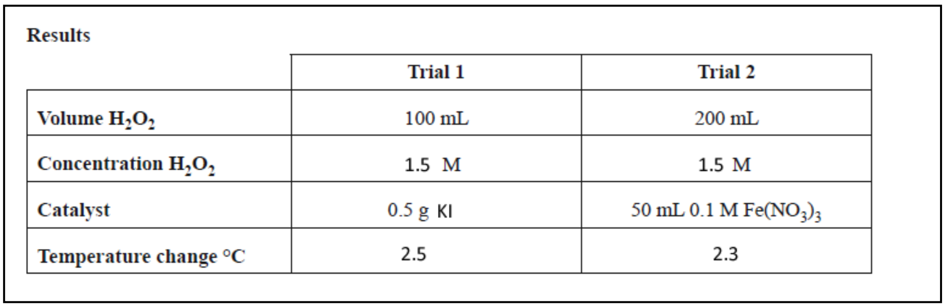
d) Both 1) and 2) are systematic errors and as such it is right to include them in the report.

Errors

1) the label on the balance indicates an error of +/- 0.005g

2) We accidentally spilled some of the precipitate when transferring it to the balance for weighing.

The following material relates to questions 6 -7



Results

	Trial 1	Trial 2
Volume H_2O_2	100 mL	200 mL
Concentration H_2O_2	1.5 M	1.5 M
Catalyst	0.5 g KI	50 mL 0.1 M $Fe(NO_3)_3$
Temperature change °C	2.5	2.3

A student conducted an investigation to understand the impact of using different catalysts on the molar enthalpy of decomposition of hydrogen peroxide according to the equation $H_2O_2(l) \rightarrow H_2O(l) + O_2(g)$.

Two trials were conducted and the results are presented in the table above.

6) What is a reasonable conclusion for this investigation?
   a) A greater molar enthalpy is achieved when KI is used as a catalyst than with $Fe(NO_3)_3$
   b) $Fe(NO_3)_3$ is not as effective as KI as catalyst for this reaction
   [✓ c)] No conclusion can be reached.
   d) $Fe(NO_3)_3$ is better at catalysing this reaction than KI

7) Another student, Jack, argued that this is not a fair test. Which comment below is true?
   a) This is a fair test as both trials use the same concentration of H_2O_2
   b) This is not a fair test as both trials need to have different concentrations of H_2O_2
   [✓ c)] This is not a fair test as both trials need to have the same amount of H_2O_2 present and the catalysts need to be in the same state and same amount while the volume of water also needs to be consistent.
   d) This is a fair test as both trials were conducted at the same room temperature and similar glassware was used and the temperature measured over the same time frame..