The determination of copper in brass

Objective

- To determine the amount of copper in a brass sample

Background

Brass is an alloy made of copper and zinc. Most brass contains about 60% copper. The proportions of zinc and copper can be varied to create a range of brasses with varying properties.

Brass is not as hard or as strong as steel, but it is harder and stronger than copper. This makes it easier to form into shapes like hexes, tubes, cylinders, and for pipes. Besides, brass is corrosion-resistant and resistant to salt water.

In this experiment, brass is reacted with nitric acid. The amount of copper ions formed is determined by two methods: (A) Microscale method - comparing the intensity of color of the solution with that of solutions of various concentrations of copper ions; (B) instrumental method - measuring the absorbance using the LED Colorimeter. Subsequently, the amount of copper in the brass can be determined.

Curriculum links

Chemistry:

Topic VII Redox Reactions, Chemical Cells and Electrolysis

Topic XIV Materials Chemistry

Combined Science (Chemistry Part):

Topic VI Redox Reactions, Chemical Cells and Electrolysis

Safety precautions

- Wear safety glasses and chemical-resistant gloves
- Conduct the reaction of brass and acid inside the fume cupboard

Chemicals (per group)

Small pieces of brass wire, about 0.3 g

5 mol dm^{-3} Nitric acid, 5 cm^3

0.5 mol dm^{-3} Copper(II) sulphate solution, about 50 cm^3

Apparatus and other materials (per group)

Plastic pipette x 8
25 cm^3 beaker x 6
50 cm^3 beaker x 2
10 cm^3 volumetric flask x 1
Plastic well-plate (24 well) x 1
10 ml measuring cylinder x 1
10 ml graduated pipette x 2
Cuvette x 7
Pipette filler
Deionized water
A piece of white paper
Disposable nitrile gloves
Washing bottle
Hot plate (shared by whole class)
Electronic balance (shared by whole class)

LED Colorimeter (per group)

Red LED x 1 (as emitter)
Infra-red LED x 1 (as detector)
Digital voltmeter x 1
3V button battery x 1
Connecting wires x 2
Blu-tack
Interlocking blocks for building a stand for holding a cuvette and two LEDs
(Note: The LED colorimeter can also be made by 3D printer)

Procedure

Preparing the brass solution (for both methods of Part A and Part B)

1. Weigh out, accurately, about 0.3 g of brass in a 25 cm^3 beaker.
2. Inside a fume cupboard, add 5 cm^3 of 5 M nitric acid using a plastic pipette into the beaker.
3. Warm the reaction mixture with a hot plate at around 60 ^oC.
4. When all the brass has dissolved, stop heating and put the beaker aside to cool down.
5. Transfer the solution to a 10 cm^3 volumetric flask. Add drops of water to the beaker to rinse and then transfer the washings to the flask. Make the volume in the flask up to the line with more water. Stopper the flask and then invert it a few times to mix.

Part A Microscale method

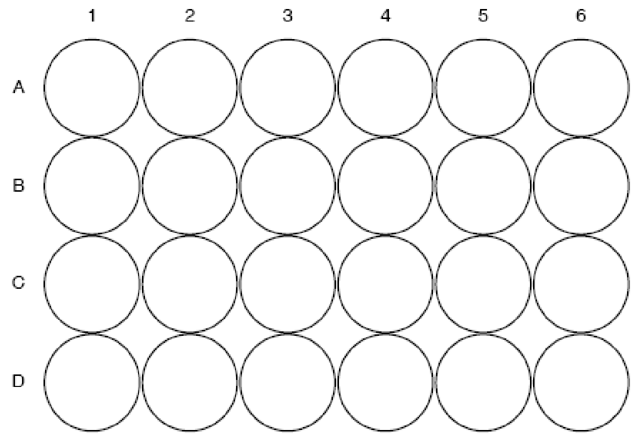

Fig. 1

1. Fill the well plate with solutions as indicated in the table below. There should be a total of 40 drops in each well.

Well No	A1	A2	A3	A4	A5	A6	C1	C2	C3	C4	C5	C6
Drops of 0.50 mol dm^{-3} copper nitrate solution	8	10	12	14	16	18	20	22	24	26	28	30
Drops of water	32	30	28	26	24	22	20	18	16	14	12	10

2. Add 40 drops of the brass solution to well B3 (See Fig. 1). Compare the intensity of the colour of the brass solution with the wells around it. A piece of white paper may be placed under the well-plate to facilitate the comparison.
3. The well that matches the intensity of colour of the brass solution represents the copper concentration in the brass solution. Calculate the copper content expressing as a percentage.

Part B Instrumental method

1. With the use of graduated pipettes / digital micropipettes, a series of diluted standard solution of copper(II) sulphate is prepared in small beakers according to the following table:

	Beaker A	Beaker B	Beaker C	Beaker D
Volume of 0.5 mol dm^{-3} $CuSO_4(aq)$ / cm^3	2	4	6	8
Volume of deionised water / cm^3	8	6	4	2
Concentration of $CuSO_4(aq)$ / mol dm^{-3}	0.1	0.2	0.3	0.4

2. Fill a cuvette at least half-full with the 0.1M standard solution (Beaker A). Clean the outer surface of the cuvette with a tissue.
3. Place the cuvette in the sample compartment of the colorimeter (see Fig. 2) and record the voltmeter reading.

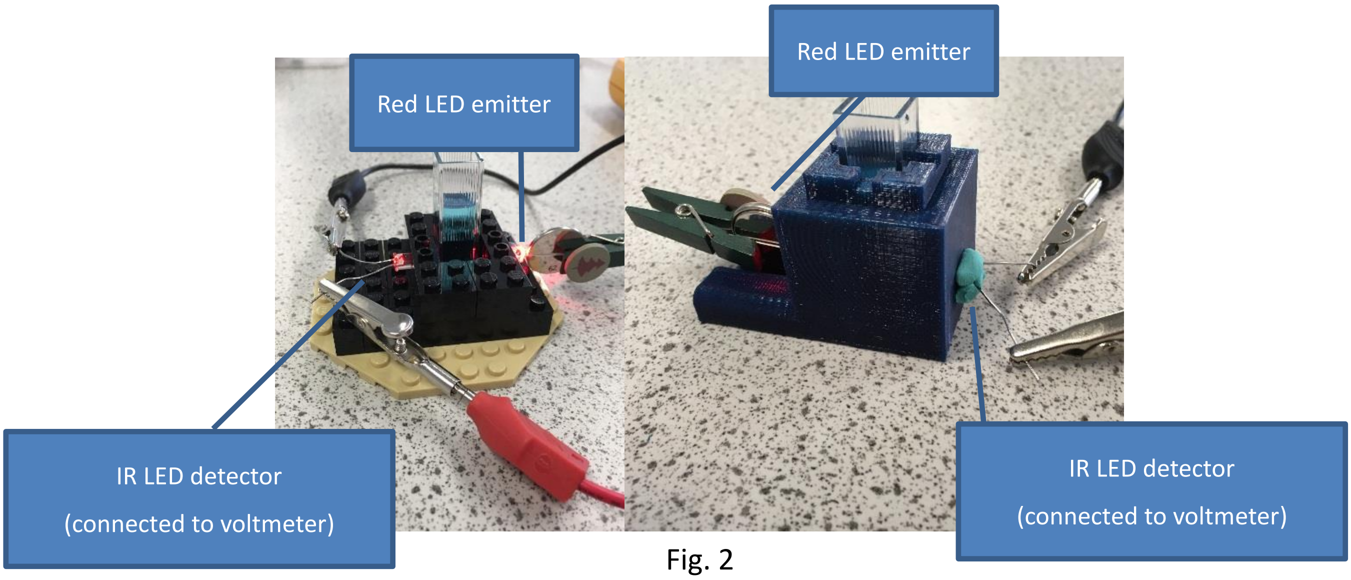

Fig. 2

4. Repeat steps 2 and 3, for deionised water and standard solutions starting from 0.2 M to 0.5 M.
5. Convert the voltages to relative absorbance and plot a graph of absorbance versus concentration for the series of standards.
6. Fill a cuvette at least half-full with the brass solution. Wipe the outside of the cuvette with a tissue to make sure that it is clean and dry.
7. Place the cuvette in the sample compartment of the colorimeter and record the voltmeter reading.
8. Convert the voltage to relative absorbance. From the calibration curve obtained in step 5, find the concentration of copper(II) ion in the brass sample.
9. Calculate the copper content expressing as a percentage.

Data and results

Part A Microscale method

1. To which well does the intensity of colour of the brass solution match?

2. Calculate the number of moles of copper in 10 cm^3 of the brass solution.

3. Calculate the mass of copper in the brass solution. Hence, find the percentage by mass of copper in the brass. (Relative atomic mass of copper = 63.5)

Part B Instrumental method

Relative absorbance = $\log_{10}(V_0 / V_s)$

where V_0 is the voltage reading with a cuvette containing just deionised water

V_s is the voltage reading with a sample in the cuvette

	Deionised water	0.1 M $CuSO_4(aq)$	0.2 M $CuSO_4(aq)$	0.3 M $CuSO_4(aq)$	0.4 M $CuSO_4(aq)$	0.5 M $CuSO_4(aq)$	Sample solution
Voltage reading / V							
Relative absorbance							

1. Plot a graph of relative absorbance versus concentration for the series of copper(II) sulphate standard solutions

2. From the above graph, the concentration of copper(II) ion in the sample = ___________________

3. Calculate the mass of copper in the brass solution. Hence, find the percentage by mass of copper in the brass. (Relative atomic mass of copper = 63.5)

<u>Questions</u>

1. Write the chemical equations for the reactions occurred in the experiment.
2. Can concentrated hydrochloric acid replace nitric acid in this experiment? Explain your answer.
3. Suggest way(s) to improve the accuracy of this experiment.

References

Part A Microscale method

J. Skinner, *Microscale Chemistry: Experiments in Miniature*. Royal Society of Chemistry, 1998.

Part B Instrumental method

1. Asheim, J.; Kvittingen, E. V.; Kvittingen, L.; Verley, R. A., Simple, Small-Scale Lego Colorimeter with a Light-Emitting Diode (LED) Used as Detector. J. Chem. Educ. 2014, 91, 1037-1039.