Relative atomic weights and the periodic table

In the 1800's when scientists were looking at arrangements of the elements, one of the few properties they could measure was an element's relative atomic weight. When elements were arranged in order of increasing atomic weight, scientists spotted patterns, with similar elements occurring at regular intervals. However early periodic tables were not complete and some elements were placed in the wrong group. In 1869 a Russian scientist, Dmitri Mendeleev, overcame the problems of the earlier periodic tables. He arranged the elements mainly in order of atomic weight, but did switch that order if the elements didn't fit the pattern. He also left gaps for elements yet to be discovered to make sure that elements with similar properties stayed in the same group.

But how did early chemists determine an element's relative atomic weight and how accurate were they?

Introduction

Dalton was one of the first scientists to attempt to determine an element's atomic weight. Since it is obviously impossible to weigh single atoms, Dalton formulated his system of atomic weights on a comparative basis. He chose the hydrogen atom and assigned 1 as its weight. The atomic weight of oxygen could then be found by analysis of the combining weights of equal numbers of oxygen and hydrogen atoms in water. At the time of Dalton's work chemical formulae were unknown. Therefore Dalton made an assumption that when two chemicals combined, the combination would always be of the simplest type. He assumed that when two elements **A** and **B** formed only one compound, then that compound would contain one atom of **A** and one atom of **B**.

Question.
A scientist called Lavoisier had analysed water and stated that it contained 85% oxygen and 15% hydrogen by weight. Use this information to determine the ratio by weight of oxygen to hydrogen in water, and hence determine the relative atomic weight of oxygen based on Dalton's assumptions.

Later scientists chose to use oxygen as a standard over hydrogen. This was for a number of reasons. Firstly hydrogen fails to form hydrides with many of the elements; hence direct determination of the combining weights of such elements with hydrogen was impossible. In contrast, most elements form stable and well defined oxides and oxides can usually be accurately analysed.

Scientists now prefer to refer to an element's relative atomic mass instead of its relative atomic weight as this will remain constant in all environments. In the experiment described in this activity, you will determine the combining masses of metals with oxygen and use the data obtained to determine the relative atomic mass of each metal.

Determining the relative atomic mass of magnesium and copper by experiment

Metals react in oxygen to form metal oxides.

metal + oxygen → metal oxide

In this experiment you will heat a known mass of two metals; magnesium ribbon and copper powder and determine the mass of each metal oxide produced. A comparison of the mass of the metal heated to the mass of metal oxide produced will allow the relative atomic mass of magnesium and copper to be determined.

Equipment

Balance (2 decimal place)

Tongs

Crucible and lid

Pipe clay triangle

Tripod

Bunsen burner

Heat resistant mat

Emery paper

Magnesium ribbon DANGER

Copper powder (non hazardous)

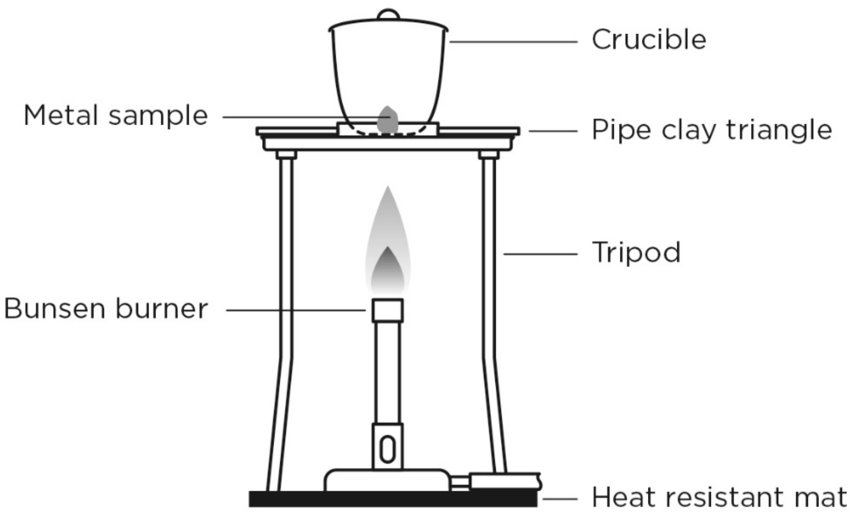
Eye ptotection

Method

Carry out the experiment described below twice, once with a 10 cm strip of magnesium ribbon (if this looks black or tarnished then clean it using emery paper) and once with approximately 2 g of copper powder.

Eye protection should be worn while heating the metals.

1. Set up the apparatus as shown in the diagram below;



2. Record the **mass of the crucible and lid empty**.

   Place the metal sample in the crucible and record the **mass of the crucible, lid and metal sample**.
3. Light the Bunsen burner and heat the crucible with a roaring flame to get the reaction to go.
4. Once the crucible is hot, gently lift off the lid with the tongs a little to allow some oxygen in. You may see the metal begin to flare up. Replace the lid if it appears that you are losing some product.
5. Keep heating and lifting the lid until you see no further reaction. At this point, remove the lid and heat for another couple of minutes. Replace the lid if it appears that you are losing some product.
6. Remove the Bunsen burner and allow the apparatus to cool.
7. Record the mass of the **crucible, lid and product**.
8. Heat the crucible again for a couple of minutes and once again allow to cool. Repeat this step until the mass of the crucible, lid and product doesn't change. This is called 'heating to constant mass.'
9. Dispose of the contents of the crucible as directed by your teacher. Copper oxide is harmful if swallowed or inhaled, damaging to the eyes and very toxic to aquatic organisms and so must be disposed of carefully.

Table 1: **Results**

	Mass in grams	
	Magnesium ribbon	**Copper powder**
Empty crucible and lid		
Crucible, lid and metal sample before reaction		
Crucible, lid and metal oxide once constant mass has been achieved		
Metal reacted		
Metal oxide produced		
Oxygen in metal oxide		

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Analysis

1. Complete Table 1 by using your experimental values to determine the mass of metal that reacted and the mass of metal oxide produced. Use the difference between the mass of the metal oxide and the mass of the metal to determine the mass of oxygen in the metal oxide.
2. Assume, like Dalton, that the metal, M and oxygen have combined in a 1:1 ratio i.e. the formula of the metal oxide is MO where M = Cu or Mg.

   Calculate the ratio of the mass of the metal to the mass of oxygen in each metal oxide and record it in Tables 2 and 3.

Table 2: **Magnesium analysis**

	Magnesium	**Oxygen**
Mass in g	:	
Ratio	:	

Table 3: **Copper analysis**

	Copper	**Oxygen**
Mass in g	:	
Ratio	:	

3. If we assume oxygen has a relative atomic mass of 16, use your results to determine the relative atomic mass of magnesium and copper.

   The relative atomic mass of magnesium based on my experiment is ________

   The relative atomic mass of copper based on my experiment is ________

Evaluation

1. How close are your values to what we now know are the true values for the relative atomic masses of magnesium and copper of 24.3 and 63.5 respectively?
2. How did you ensure that your results were as accurate as possible?
3. What sources of error are there in your experiment? How could these be removed?
4. What problems might these experimental results have caused the early chemists? How did Mendeleev get round some of these problems?

