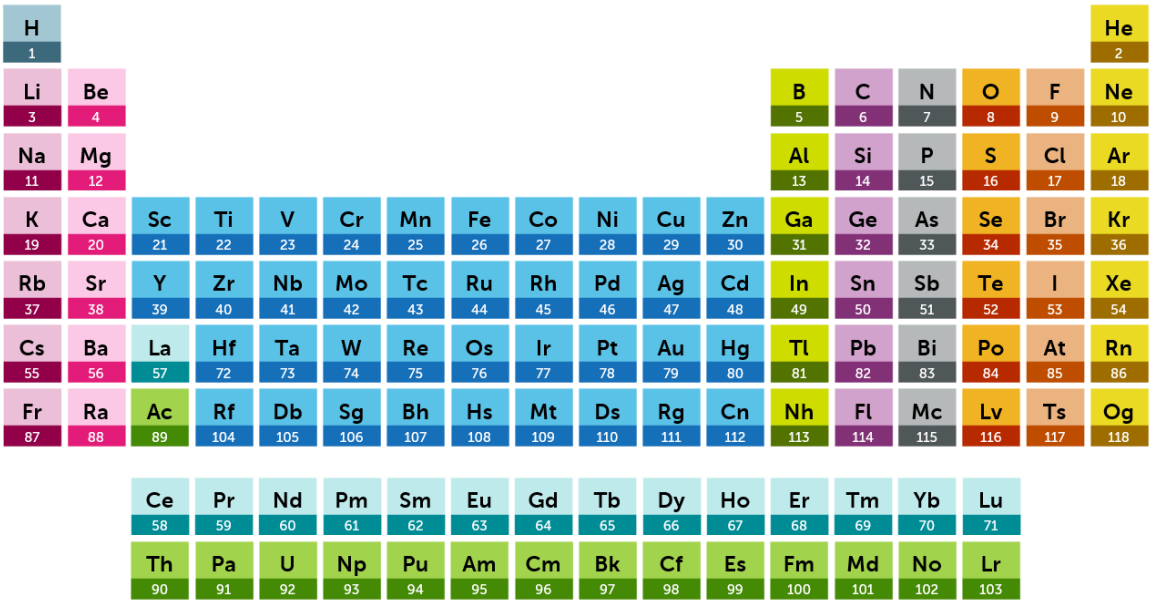
Top of the Bench 2022 Practical Challenge

PRECIOUS ELEMENTS



We rely on elements in every aspect of our daily lives; for getting from place to place, for our health, for our food supply, for energy and for communication. Yet the supply of many elements is not infinite. Therefore, it is important that we reuse and recycle materials as much as possible.

An alloy is a mixture of two or more elements where at least one element is a metal. Alloys have properties that are different to the pure metal from which they are made. These properties often make the alloy more useful.

Before alloys can be reused or recycled it is important to identify the metals they contain and the quantities in which they are present. In this task you will use your knowledge of metals and their reactions to investigate two different alloys.

The first is an alloy that is used to remove unwanted gases from vacuum tubes in for example old fashioned televisions and computer screens.

The second is the alloy used for 2p coins. Pre-1992 one and two pence coins were produced mainly from copper. However over recent years the wide range of applications of copper increased demand and as a result the price of copper increased to the point where the monetary value of a one and two pence coin was less than that of their copper content. Therefore since 1992 one and two pence coins have been made from mild steel and plated with copper. In the second part of the practical you will determine the mass of copper present in one of these new 2p coins.

Part 1 – Using chemical tests to identify the metals present in an alloy

A sample of the alloy taken from the vacuum tubes in an old television was reacted with an excess of concentrated nitric acid and diluted with water. This produced an aqueous solution containing the metal ions of any metals present in the alloy.

You are provided with a sample of this solution – labelled **Solution X**.

In this part of the practical task, your job is to identify the two metal ions present in the aqueous solution, and therefore the two metals present in the alloy.

Method

1. Place about 1 cm^3 of **Solution X** into three test tubes.

2. To the first test tube add aqueous NaOH drop wise. Gently shake the tube after the addition of each drop and record your observations in **Table 2** on the results sheet.

   Continue to add aqueous NaOH until present in excess when no further change will be seen. Record any observations on adding an excess in **Table 2**.

3. To the second test tube add aqueous ammonia drop wise. Gently shake the tube after the addition of each drop and record your observations in **Table 2** on the results sheet.

   Continue to add aqueous ammonia until present in excess when no further change will be seen. Record any observations on adding an excess in **Table 2**.

4. To the third test tube add dilute sulfuric acid drop wise. Gently shake the tube after the addition of each drop and record your observations in **Table 2** on the results sheet.

5. Use the information in **Table 1** (over) to infer the identity of the two metal ions present in the solution and hence the two metals present in the alloy.

   Write your answer on the answer sheet.

Once you have identified the metals present in the alloy take your answer to the demonstrator to receive the equipment and instructions for Part 1B of the practical.

Table 1: The reactions of aqueous metal ions

Metal ion in solution	Observation	
	On addition of a little aqueous NaOH solution	On addition of an excess of aqueous NaOH solution
aluminium	white precipitate	precipitate dissolves to form a colourless solution
barium	no precipitate formed	no change
calcium	white precipitate	no change
chromium	grey/green precipitate	precipitate dissolves to form a green solution
copper	blue precipitate formed	no change
manganese	pale brown precipitate	precipitates darkens on standing in air

Metal ion in solution	Observation	
	On addition of a little dilute ammonia solution	On addition of an excess of dilute ammonia solution
aluminium	white precipitate	no change
barium	no precipitate	no change
calcium	no precipitate formed	no precipitate formed
chromium	grey/green precipitate	precipitate dissolves to form a purple solution
copper	blue precipitate formed	blue precipitate dissolves to formed a deep blue solution
manganese	pale brown precipitate	precipitates darkens on standing in air

Metal ion	Observation on dropwise addition of sulfuric acid
aluminium	no precipitate formed
barium	white precipitate formed
calcium	small amount of a white precipitate formed
chromium	no precipitate formed
copper	no precipitate formed
manganese	no precipitate formed

Part 2 – Quantitative analysis to determine the composition of a 2p coin

In this part of the practical activity you will use chemical analysis to determine the mass of copper in a single 2p coin.

When copper reacts with concentrated nitric acid, copper(II) nitrate, nitrogen dioxide and water are formed. The equation for the reaction is given below;

$$4HNO_3(aq) + Cu(s) \rightarrow Cu(NO_3)_2(aq) + 2NO_2(g) + 2H_2O(l)$$

As nitrogen dioxide is a toxic gas this reaction has been carried out for you. The details are given below.

*Five 2p coins were reacted with an excess of concentrated nitric acid and the residue made up to 250 cm^3 by the addition of water. You are provided with this solution labelled **Sample Z**.*

Method

1. Make up a standard solution of 6.4 g of hydrated copper(II) nitrate dissolved in 250 cm^3 of water. Hydrated means that the salt contains additional water.

   This solution contains 5.0 g of $Cu(NO_3)_2$ per 250 cm^3.

2. Dilute portions of this solution with water to produce 5 cm^3 each of a solution of copper(II) nitrate with concentrations of 0.0, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5 and 5.0 g per 250 cm^3.

   Place each solution in a test tube.

   Complete **Table 3** on the Results sheet to show how you did this.

3. Use the spectrophotometer to record the absorbance **at 800 nm** of each solution to **2 decimal places**.

   Use the sample containing 0.0 g of copper(II) nitrate per 250 cm^3 as the blank.

   Record the values in **Table 3**.

4. Plot a graph to show how the absorbance of the solution changes with concentration.

5. Record the absorbance of **Sample Z** - the solution of copper(II) nitrate produced from the reaction of five 2p coins with an excess of concentrated nitric acid to **2 decimal places**.

   Record the value in **Table 3**.

6. Use the absorbance recorded in step 5 together with the graph plotted in step 4 to determine;

   a. the mass of **copper nitrate** in 250 cm^3 of **Sample Z**

      and hence

   b. the mass of **copper** in a **single** 2p coin.

      Relative atomic masses, A_r: Cu = 63.5; N = 14; O = 16

Part 2 Extension activity

The copper in a 2p coin is used to plate or thinly coat a coin made from mild steel

If the 2p coin has a diameter of 25 mm, calculate the thickness of the copper coating in mm.

Density of copper = 8.96 g/cm^3

Area of a circle = πr^2

You can assume the coin itself has minimal thickness

Show your working and record your answer on the Results sheet.

TOP OF THE BENCH 2020 PRACTICAL CHALLENGE

Precious elements - Results

School name:.....

Part 1 **/ 14** **Part 2** **/ 16** **Overall Score** **/ 30**

Demonstrator comments:

Part 1a – Using chemical tests to identify the metals present in an alloy

Record your observations in **Table 2** below.

Table 2

Test	**Observation**
Addition of a little aqueous NaOH solution	
Addition of an excess aqueous NaOH solution	
Addition of a little aqueous NH_3 solution	
Addition of an excess aqueous NH_3 solution	
Addition of H_2SO_4 dropwise until present in excess	

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Based on our observations the elements present in Alloy **X** are;

_____ and _____

2

Part 2 – Quantitative analysis to determine the composition of a 2p coin

Table 3

Concentration of $Cu(NO_3)_2$ solution in g per 250 cm^3	Volume of 5 g per 250 cm^3 solution of $Cu(NO_3)_2$ solution in cm^3	Volume of water added in cm^3	Absorbance at 800 nm (to 2 d.p.)
0.0	0.0	5.0	
0.5			
1.0			
1.5			
2.0			
2.5			
3.0			
3.5			
4.0			
4.5			
5.0	5.0	0.0	

2

	Absorbance at 800 nm (to 2 d.p.)
Sample Z Solution produced from the reaction of five 2p coins with an excess of nitric acid	

1

The mass of copper(II) nitrate in the 250 cm^3 solution produced from the reaction of five 2p coins with an excess of nitric acid is _____ g.

The mass of copper in a single 2p coin is _____ g. Give your answer to 2 decimal places.

3

Part 2 Extension activity

The thickness of the coating of copper on a 2p coin is _____ mm (to 2 sig fig)

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