Student sheet

In this practical I will be:

- Using my scientific knowledge and understanding to explain what is meant by an alloy.
- Producing an alloy (solder)
- Analysing how the properties of my alloy differ from its constituent elements.
- (Extra) Calculating the density of my alloy, and comparing this with the densities of the constituent elements.

Introduction:

You are working on a piece of jewellery for a client which requires several delicate pieces of silver to be joined together. You know that plumbers often use join metal pipes in peoples' houses using a mixture of tin and lead, called solder.

Unfortunately, you don't know what the ratio of metals is best, so like all good science-artists, you decide to investigate further…

Equipment per group:

- Eye protection
- Thermal protection gloves
- Lead turnings (**TOXIC**) 2 g
  (In countries where lead is prohibited for use in school then the tin–silver–copper combination can be used as reliable and easy to work with as a replacement for the lead. If this is chosen as the route, then the formulation is 95.5% tin, 3.9% silver, 0.6% copper. It is known as SAC solder from the chemical symbols of each of the elements (Sn, Ag, Cu). In this case the quantities of metals per group should be 7.95 g tin, 0.325 g silver and 0.5 g copper. Ignore the tin quantity given below.)
- Tin turnings 2 g
- Carbon powder 2 g

Each working group requires:

- Crucible
- Pipe clay triangle
- Bunsen burner
- Tripod
- Heat resistant mat
- Spatula
- Tongs
- Casting sand- enough to fill a sand tray.

- Metal sand trays or sturdy metal lids- 2, or white tile
- Balance
- Stirring rod

Method:

Wear eye protection.
Tie long hair back.
Open windows to provide adequate ventilation.
Wash hands after concluding the activity

Making the alloy:

1. If using casting sand, fill one of the sand trays with casting sand and push your finger into it to make an indent. This is your cast.

2. Use a balance to weigh out 1g of the tin turnings and keep to one side

If following the non-lead route then put 7.95 g of tin into the crucible first. Ignore 3 below.

3. Weigh 1g of lead turnings into the crucible.

4. Put the crucible onto a pipe clay triangle. Rest this on a tripod on a heat resistant mat and make sure that it is stable.

5. Heat the crucible strongly with a Bunsen burner until the lead (tin) is molten- this should not take longer than 5 minutes.

6. Add a spatula of carbon powder to the top of it to prevent a skin forming.

7. Add the tin to the molten lead and stir with a stirring rod until both metals are molten and thoroughly mixed.

If following the non-lead route than you add 0.5 g copper and 7.95 g silver to the molten tin and carbon. Mix the molten metals thoroughly then follow 8 below.

8. Move the Bunsen away from the tripod and put it onto a yellow flame.

9. Wearing thermal protection gloves and eye protection, pick up the crucible using the tongs, and pour the molten metal into the cast or onto a ceramic tile.

10. Take great care as you do this to avoid splashing or dripping of the molten metal.

11. Let it cool down completely before you touch it.

Testing the alloy:

Hardness testing

- Try to scratch the alloy with the metals that made the alloy and with the alloy itself.
- Also try to scratch each metal with the other metals.
- The one which does not scratch the other is the hardest.
- Which metal is the hardest?
- Is the alloy harder or softer than either of the metals?

Density testing

- Hold the metals in one hand and the alloy in the other.
- Which seems to be the heaviest/most dense?

Melting-point testing

- Put the alloy, a piece of each metal, both about the same size as the alloy, onto a sand tray.
- They should all be the same distance from the middle of the dish.
- Heat the dish gently in the middle.
- When the metals have melted, stop heating.
- Which metal melts the first?
- Which metal melts second?

Comparing all the answers from the tests make some deductions about the way the properties of the alloy are the same or different from the starting metals.

Going further:

- Find the mass of a piece of the alloy.
- Work out the volume of the same piece by the displacement method.
- Then calculate the density using the formula:

$$Density = \frac{Mass}{Volume}$$

Compare the density of the solder alloy with the density of the starting metals.

Try repeating the activity but varying the proportions of metals to tin and see if it makes a difference to the properties of the solder.

Theory:
In everyday language, we often use the word metal to describe what an alloy is. In its scientific usage, the term metal means a metallic element.

A mixture of metallic elements is called an alloy. So, iron (an element) is a metal; but steel (a mixture of iron with other elements such as carbon, nickel, chromium, etc.) is an alloy.

An alloy is a mixture of either pure or relatively pure chemical elements, forming an impure substance retaining the characteristics of a metal.

An alloy is distinct from an impure metal, such as wrought iron, in that, with an alloy, the added impurities are usually desirable and will typically have some useful benefit.

Alloys are made by mixing two or more elements; at least one of which being a metal. This is usually called the primary metal or the base metal, and the name of this metal may be the name of the alloy. The other constituents may or may not be metals but, when mixed with the molten base, they will be soluble, dissolving into the mixture.

When the alloy cools and solidifies (crystallizes), its properties will often be quite different from those of its individual constituents.

The alloy solder can be made by heating together the metals lead and tin. Tin/lead solders, are also called soft solders, contain tin concentrations between 5% and 70% by weight.

Alloys commonly used for electrical soldering are 60:40 tin/lead (Sn/Pb). This type of solder melts at 188°C

In plumbing, metal pipes are joined together with an alloy called solder. In the past, a high proportion of lead was used in the alloy, typically 50:50 tin: lead. This made the alloy solidify more slowly, so that it could be wiped over the joint to ensure it was watertight, before soldering.

When the significance of lead poisoning was fully appreciated lead water pipes were no longer used, and copper pipes were used instead. But lead solder was still used until the 1980s. More recently, research has shown that even small amounts of lead can be detrimental to health, so lead in plumbing solder was replaced by silver (food grade applications) or antimony, with copper often added, and the proportion of tin was increased.