Teacher and Technician sheet

In this practical students will:

- Use their scientific knowledge and understanding to explain what is meant by an alloy.
- Produce an alloy (solder)
- Analyse how the properties of solder differs from its constituent elements.
- (Extra) Calculate the density of their alloys, and compare this with the densities of the constituent elements.

Introduction for Teachers:

This activity could open with a discussion about alloys.

- Do they know what an alloy is?
- What they are used for?
- Where we might see alloys in the world around us?

This is designed to gain some perception of the ideas students have about glass as a material. For reference the following notes might help. The key words for this activity are:

- Mixture;
- Metal;
- Element;
- Crystal.

In its scientific usage, the term metal means a metallic element. An **alloy** is a mixture or solid solution composed of a metal and another element. But in everyday language, we often use the word metal to describe what an alloy is. That is because a mixture of metallic elements is called an alloy. Iron is a metal element. Steel is a mixture of iron with other elements such as carbon, nickel, chromium, etc. and so 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. Alloy constituents are usually measured by mass.

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.

Unlike pure metals, most alloys do not have a single melting point; rather, they have a melting range in which the substance is a mixture of solid and liquid. When the alloy cools

and solidifies (crystallizes), its mechanical properties will often be quite different from those of its individual constituents.
A metal that is normally very soft and malleable, such as aluminium, can be altered by alloying it with another soft metal, like copper. Although both metals are very soft and ductile, the resulting aluminium alloy will be much harder and stronger.

Adding a small amount of non-metallic carbon to iron produces an alloy called steel. Due to its very-high strength and toughness (which is much higher than pure iron), and its ability to be greatly altered by heat treatment, steel is one of the most common alloys in modern use. By adding chromium to steel, its resistance to corrosion can be enhanced, creating stainless steel, while adding silicon will alter its electrical characteristics, producing silicon steel.

Hence alloys may be a homogeneous solid solution, a heterogeneous mixture of tiny crystals, a true chemical compound, or a mixture of these. Alloys are used more extensively than pure metals because they can be engineered to have specific properties. This leads to a number of definitions of different types of alloys:

- **amalgam** an alloy containing mercury;
- **eutectic mixture** a mixture of substances having a melting point lower than that of any of its components;
- **microstructure** the fine structure of a pure metal or alloy, as revealed by magnifications of 25x or greater.
-

The alloy solder can be made by heating together the metals lead and tin.

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.

Tin: lead solders, also called soft solders, with tin concentrations between 5% and 70% by weight. Alloys commonly used for electrical soldering are 60:40 Tin: lead (Sn: Pb) which melts at 188°C.

In plumbing in the past, a high proportion of lead was used, commonly 50:50. This made the alloy solidify more slowly, so that it could be wiped over the joint to ensure it was watertight, before soldering. Lead water pipes were displaced by copper when the significance of lead poisoning was fully appreciated but lead solder was still used until the 1980s. Since even small amounts of lead have been found detrimental to health lead in plumbing solder was replaced by silver (food grade applications) or antimony, with copper often added, and the proportion of tin was increased.

Curriculum Range:
This practical is really designed for secondary students and the aim is to gain some understanding of the way the materials are used to create artefacts. It links with:

- Setting up simple practical enquiries, comparative and fair tests;
- Reporting on findings from enquiries and observations, including oral and written explanations, displays or presentations of results and conclusions;
- Using straightforward scientific evidence to answer questions or to support their findings;
- Build a more systematic understanding of the chemistry of metals and alloys by exploring the way metals can be used to make a different substance with useful properties;
- Ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience;
- Use appropriate techniques, apparatus, and materials during laboratory work, paying attention to health and safety;
- Make and record observations using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements;
- Present observations using appropriate methods;
- Interpret observations and identify patterns using those observations to draw conclusions;
- Present reasoned explanations, including explaining data in relation to predictions and hypotheses;
- Learn about the concepts of mixture, metal, element and crystal.

Hazard warnings:

Wear eye protection.
Tie long hair back.
Wash hands after concluding the activity

- Lead, Pb(s), (**HARMFUL IF SWALLOWED OR INHALED, REPRODUCTIVE TOXIN, SPECIFIT TARGET ORGAN TOXIN ON REPEATED EXPOSURE**)- see CLEAPSS *Hazcard/SSERC hazardous chemicals database*
- Tin, Sn(s) - see CLEAPSS *Hazcard/ SSERC hazardous chemicals database.* (Low hazard)
- Carbon, C(s) - see CLEAPSS *Hazcard/ SSERC hazardous chemicals database.* (probably an **EYE / RESPIRATORY IRRITANT**)

ROYAL SOCIETY OF CHEMISTRY

It is a useful precaution to check the tongs since some tongs in schools do not grip well and the hinges often stick. Ask your technicians to check them before starting the experiment. Casting sand may be available from the school Design and Technology or art departments. If unavailable from these departments it is possible to use a ceramic tile (old bathroom tile) for small quantities. If a tile is used, a sand tray will not be required.

Materials (Equipment):

- Eye protection
- Thermal protection gloves
- Lead (HARMFUL IF SWALLOWED OR INHALED, REPRODUCTIVE TOXIN, SPECIFIT TARGET ORGAN TOXIN ON REPEATED EXPOSURE) 2 g
- Tin 2 g
- Carbon powder (EYE/RESPIRATORY IRRITANT) 2 g

Each working group requires:

- Crucible
- Pipe clay triangle
- Bunsen burner
- Tripod
- Heat resistant mat
- Spatula
- Tongs
- Casting sand
- 2 Metal sand trays or sturdy metal lids or white tile
- Balance
- Stirring rod

Technical Notes:

The most likely incident in this experiment is a student burning themselves, so warn them about the equipment being hot.

If students are not sure how to use tongs correctly (pouring molten metal can be hazardous and lead to burns) it is worth demonstrating how to use them safely. Some tongs in schools do not grip well. Technicians must check them before starting the experiment.

Lead is a toxic metal and if it is heated for too long or too high above its melting point it can start to give off fumes. Ensure that the laboratory is well-ventilated. Warn students not to breathe the fumes given off by their experiment and tell them to heat the metals for the shortest time possible to get them to melt. Wash hands after handling lead.

ROYAL SOCIETY OF CHEMISTRY

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).

The experiment should be completed in 40 minutes. However, this depends on the experience and practical abilities of the students. Further time may be required for allowing the equipment to cool before it can be put away.

The expected results of the tests are that the alloy is clearly harder and scratches the lead. The lead does not leave a mark on the alloy.

The density of the alloy should be less than that of the lead, but this test is subjective. The lead melts first, followed by the tin. The alloy has the highest melting point – demonstrating clearly very different properties from its constituent metals.

Results:
The metals melt (within 5 minutes) and, when the other metals are added to it, they fuse in the carbon powder.

The alloy is easy to produce in a crucible on a pipe clay triangle.
If the alloy has fused properly it can be separated from the carbon when cooled and then weighed. There may be some loss due to smaller parts not fusing properly or being left in the carbon powder.

The alloy can be left to cool in the sand/crucible or placed into a beaker of water. Drain the excess water and dry using filter paper.

The alloy is harder than the constituent metals and takes longer to melt than lead or tin.

Taking the work further:
To more accurately determine the density of the solder.

To add in some mathematics you could get the students to weigh the alloy to find the mass. Then to work out its volume by displacement of water in a Measuring cylinder or a Eureka can. They could then calculate the density from the formula:

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

They can then compare the density of the solder alloy with the lead and tin they added.

ROYAL SOCIETY OF CHEMISTRY