Ri Christmas Lectures® 2012: The Modern Alchemist

Teaching Resource - Group 1 Flame Tests

Overview:

This resource contains information based around flame tests, and emission spectroscopy; the background information is supported by video clips based around the 2012 Christmas Lectures®, and ideas for practical and further work.

Flame Tests:

Flame tests are a common form of basic analytical test carried out to identify relatively small amounts of certain metals. The test involves strongly heating small samples of metal within a flame (such as a Bunsen burner), and observing the colour of the flame.

Flame tests are commonly used to identify samples of Group 1 metals, as the colours that are generated are easily distinguishable from one another (See below, Group 1 flame tests). However, flame tests can be used to help in analysis of other metal samples.

Flame tests - A Basic Procedure:

- Equipment:
    - Nichrome wire (or Platinum wire, although this is very expensive) - ideally mounted on a glass rod
    - Concentrated hydrochloric acid (although dilute acid can be used in the classroom due to the hazards of working with concentrated acids)
    - Bunsen burner
    - Metal salts
- Procedure:
    - Dip the nichrome wire into the acid, then wipe thoroughly with dry tissue paper (wear gloves).
    - Re-dip the cleaned nichrome into the acid, then into the metal salt to be tested, ensuring a small amount sticks to the wire.
    - Hold the coated wire into the lit roaring Bunsen burner flame, and observe the colour of the flame.
    - If the colour observed is not strong enough, recoat the wire with the metal salt and try again - sometimes, dipping the coated wire into the acid and then placing it into the flame can sometimes produce a short bright flash of colour.
    - After the test, clean the nichrome wire with the acid thoroughly, and then the test can either be repeated, or another salt tested.

- Care - the nichrome wire will be very hot when exposed to the Bunsen flame. Care should also be taken when using acids - gloves and eye protection should be worn at all times.

Flame tests - Pros and Cons:

There are several advantages and disadvantages to the use of flame tests, and these should be considered by any student or teacher looking to use them in a Lab.

- Advantages:
  - Flame tests are easy, inexpensive, and quick to carry out - they can be repeated many times, and easily compared side by side. The repeatability of a flame test means that the scientist carrying out the test can be more confident in the results that they observe.
- Disadvantages:
  - Basic flame tests rely upon the individual scientist to observe the colours produced (they are subjective). Therefore, the results for one sample can vary depending on the scientist who carries out the experiment.

Flame Tests Videos - The Group 1 Metals:

- Lithium
  - Symbol: Li *Observed Colour: Red*
    - Lithium Flame Test
- Sodium
  - Symbol: Na *Observed Colour: Strong Yellow/Orange*
    - Sodium Flame Test
- Potassium
  - Symbol: K *Observed Colour: Lilac (Pink)*
    - Potassium Flame Test
- Rubidium
  - Symbol: Rb *Observed Colour: Red/Purple*
    - Rubidium Flame Test
- Caesium
  - Symbol: Cs *Observed Colour: Blue/Violet*
    - Caesium Flame Test

Flame Tests - Emission Lines and Spectroscopy:

As mentioned above, the simple classic flame test relies upon the eyes of the scientist to determine the results. This means that the results are subjective - two different people may not see the same colours, or describe them in the same way.

An improvement on the method would be to use something measurable to determine the colour of the light given off during a flame test - this is where spectroscopy comes in.

Spectroscopy is the study of the interaction of matter and radiated energy (such as light and other forms of electromagnetic radiation). By using an instrument called a 'spectrometer', scientists can measure the wavelengths of light being given off during a flame test. This produces a graph that is called a 'spectrum' and is unique to each element. Therefore, by comparing the spectrum with a known sample, the metal that was tested can be identified without doubt.

For flame tests, the spectrum that is recorded is called an 'emission spectrum' as the light that we see is emitted from the metal ions that are tested.

Flame Tests - Where Does the Colour Come From?

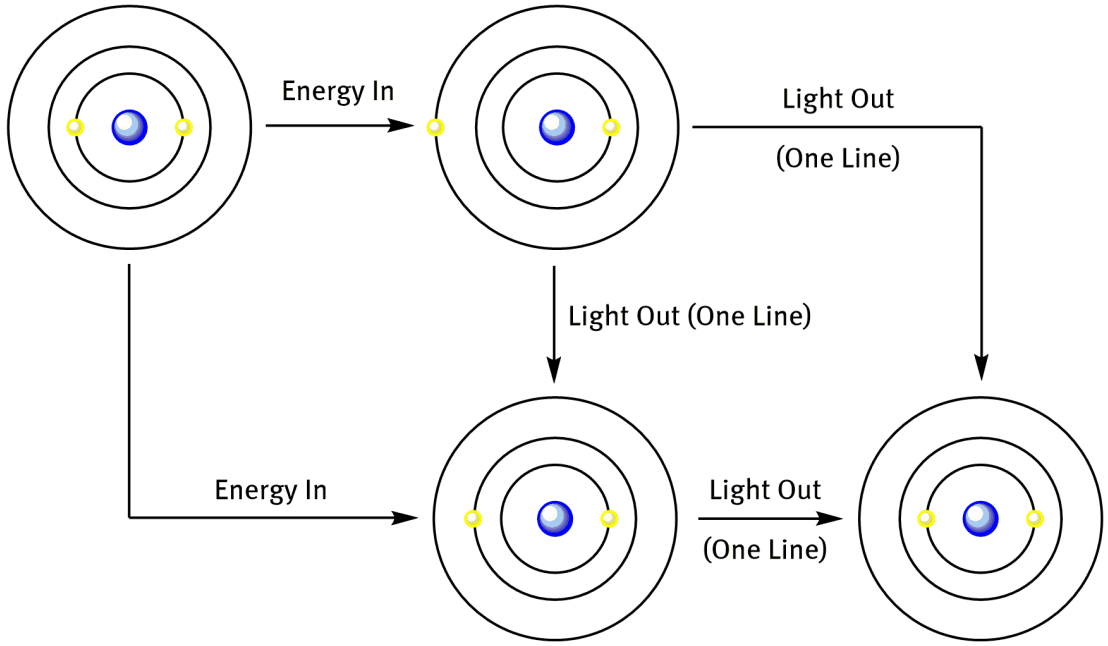
We now know that each element has a unique spectrum, and we can use these to determine which element is present in a flame test. However, what gives rise to these unique spectra, and where do the colours come from?

When a metal ion is heated strongly in a flame, the outer electrons can absorb energy and become excited. This means they move from a low energy state to a higher energy state - they move from the outer energy level (shell) of the atom to any of the higher unoccupied levels (which unoccupied level depends upon the amount of energy they absorb from the flame).

However, the excited state electrons are often unstable, and will return to the low energy state. In order to do this they have to lose the extra energy that they absorbed. This energy is lost in the form of light - the light that we see from the flame.

The colour of light which we see is made up of many individual emissions - the lines seen in the emission spectrum of the element in question. There are generally many lines in the emission spectrum, as although the excited electrons have to return to the ground state, they do not have to do so all in one go - they could return halfway, emitting a specific wavelength of light (one line), then descend the rest of the way (giving a second line).

Below is an example of this phenomenon:



In the diagram above, there are three different transitions, which each give out a different wavelength of light. Therefore, the spectrum for the atom above would contain three different lines.

View the full 2012 Ri Christmas Lectures® - The Modern Alchemist, along with behind the scenes footage, and related content, at the Ri Channel[1].

[1] The Ri Channel, www.richannel.org