

University of Wales Trinity Saint David

Analysing the effectiveness of Flame spectroscopy

Ordinance Munitions and Explosives ACDB4011

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Introduction

Spectroscopy is a form of analytical chemistry that is used to study the structure of atoms and molecules. It offers a precise form of analysis to determine the various configurations of ground and excited states of an electron. A simple way to detect unknowns in a solution is a Flame Test. This report outlines the test performed to verify the validity and subsequent effectiveness of the Flame Test method.

Flame spectroscopy is a relatively simple way of showing the metallic spectra in an unknown solution by observing the flame colour after the solution has been set alight, usually over a Bunsen burner, an easy test that requires little to no effort to obtain results. The purpose of the study undertaken was to test the effectiveness of flame test spectroscopy and the reliability of the results when 8 unknown solutions were given.

Theory

The flame test works by thermal energy exciting the electrons, thus moving the electron from its ground state. The visible light that is released is a by-product of energy transfer of the electron returning to its ground state, and when this happens, a photon is produced. The colour of the light is connected to the location of the electrons and the affinity the outer-shell electrons have with the atomic nucleus. Electromagnetic radiation is composed of oscillating waves in the electromagnetic spectrum. Wavelength is defined as the distance between the peaks and troughs on a wave and is measured in metres, the frequency is the amount of full waves pass a predefined point every second. These waves are measured in Hertz (Hz). Electromagnetic waves travel at the speed of light (c) or $2.998 \times 10^8 \text{ m/s}$ the equation is given as:

$$c = \lambda \times v$$

The energy difference between the high energy level and the low energy level is related to the frequency of the emitted light given as the equation:

$$\Delta E = h \times f$$

Where ΔE is the energy difference between levels, h is a Planck constant ($h = 6.63 \times 10^{-34} \text{ Js}$) and f is the frequency of light in Hz (s^{-1}). Frequency and the wavelength λ are inversely proportional shown in the equation:

$$c = f \times \lambda$$

As can be seen by figure 1, the visible light spectrum is based entirely on the wavelength that can be seen by the human eye.

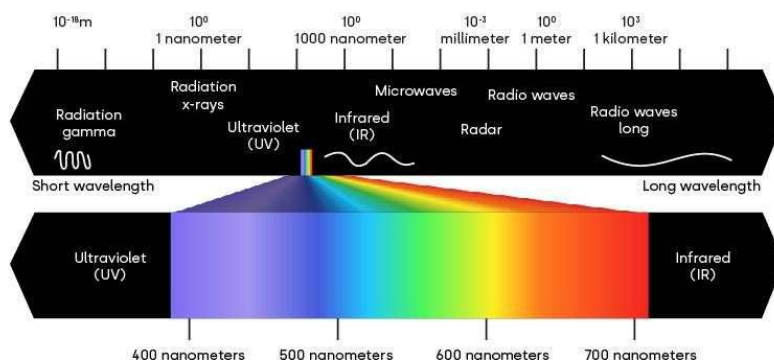


Figure 1 Wavelength in nanometres [1]

In the explosives industry, flame test spectroscopy is used to measure the lead content in soil samples. A lot of cast double base propellants use heavy metals such as lead for ballistic modifiers. During disposal and burning these metals can seep into the soil. For environmental and safety reasons flame spectroscopy is used to test for these metals.

Results

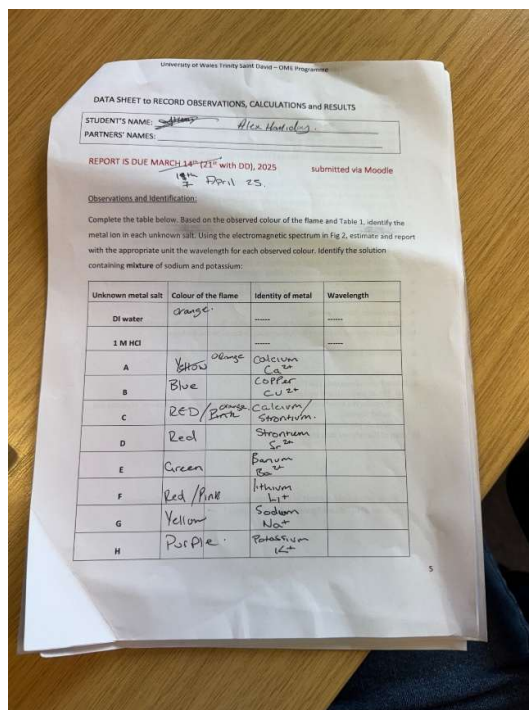


Figure 2 Physical results of experiment

Table 1 Results from experiment

Unknown Metal salt	Colour of flame	Identity of metal	Wavelength
A	Orange	Calcium Ca^{2+}	600nm
B	Blue	Copper Cu^{2+}	450nm
C	Red/Orange	Calcium/Strontium	680nm
D	Red	Strontium Sr^{2+}	700nm
E	Green	Barium Ba^{2+}	530nm
F	Red/Pink	Lithium Li^+	650nm
G	Yellow	Sodium Na^+	590nm
H	Purple	Potassium K^+	400nm

Discussion

The results gathered cannot be given as 100 per cent accurate as they depend entirely on the colour perception of the individual observing the flame. The concentration of the metal salts in the solution would potentially change the intensity of the flame. These findings support the hypothesis that the different metal salts would produce different colours of flames.

Errors could be caused by equipment limitations as the test is done using a Bunsen burner and the naked eye, this can cause measurement inaccuracies in the determination of the colour of the flame. These factors may have led to incorrect assumptions of the wavelength.

The experiment can be made more accurate by using a flame photometer, this apparatus is very sensitive and measures the wavelength to the nanometre to provide the most accurate reading. Further experiments could also be conducted in absence of the flame photometer to attempt to verify results, it would also be possible to perform the test in a darkened room with a camera to record the flame colour change.

Conclusions

Overall, the experiment was partially successful to demonstrate the concept of flame testing. However, to be more accurate further investigations are required either using more sophisticated equipment or more iterations of the tests carried out.

The data gathered contributes to a better understanding of flame test spectroscopy and highlights the importance of conveying information correctly to determine outcomes of the experiments.

Appendix

The methods and apparatus have been taken from the handout sheet given in the experiment brief.

Lab tools and equipment

- Bunsen burner
- Heat-resistant mat
- Matches
- Metal rod
- 1M solutions of unknown metal salts labelled A-H
- Beaker with 1M HCL
- Beaker with deionised water
- Blue cobalt glass

Procedure

1. Set up a Bunsen burner on the surface of the heat resistant mat. Light it and open the air vent to obtain a non-luminous flame with two blue cones. Ensure the safety yellow flame is on when the Bunsen burner is not in use.
2. To clean the wire, dip it into the 1M HCL and heat in the hottest part of the flame. This step is repeated until no colour is shown.
3. Dip the wire in the deionised water and heat as before to remove any residue of HCL from the cleaning step. Repeat step 3 and 4 before each test.
4. Cool down the wire and dip it into the unknown solution. Heat the wire in the hottest part of the flame. Record observations. Use the blue cobalt glass to identify the mixture of sodium and potassium.
5. Repeat steps 2 – 4 for all other samples.
6. Record the colour of the flame for deionised water and 1M HCL.

Works Cited

- [1] "Lena Lighting," [Online]. Available: <https://lenalighting.com/?view=article&layout=blog&id=1795&catid=137>. [Accessed 01 04 2025].