

Analysing the effectiveness of Flame Test Spectroscopy

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ABSTRACT

Spectroscopy is a form of analytical chemistry 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. Spectroscopy has also seen use in astronomy to conclude that the universe is expanding rapidly and isotropically thanks to the spectral emission lines of distant galaxies. However, a far simpler way to detect unknowns in a solution is a Flame Test. This report outlines the undertaken test to verify the validity and subsequent effectiveness of the Flame Test method.

1 INTRODUCTION

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 ascertain results. The purpose of the undertaken study was to test the effectiveness of flame test spectroscopy and the reliability of the results when given 8 unknown solutions. Myself and my lab partner Tom Volpato conducted this test using standardised lab methods.

2 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 when this happens a photon is produced¹. The color of the light is connected to the location of the electrons and the affinity the outer-shell electrons have to the atomic nucleus. Electromagnetic radiation is comprised of the 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: $c = \lambda \times v$. As

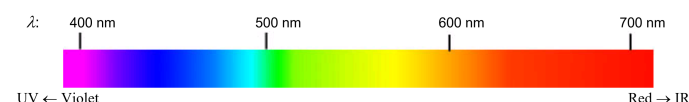


Fig. 1. The Visible light spectrum

can be seen from figure 1 the visual light spectrum is based purely off the wavelength that can be seen as visible light, however within the same

wavelength spectra there is also microwaves, radiowaves, ultraviolet waves and x-rays but to name a few. There have been developments in spectroscopic techniques in the detection of explosives using a method known as Terahertz Spectroscopy. It uses electromagnetic radiation in the frequency of 0.1 to 10 THz ³ it can detect physical phenomena such as rotation and vibration transitions for molecules, collective vibration or torsion modes for condensed-phase materials. This means that due to the instability of explosives using this frequency can detect the vibrations of particles in close proximity with each other. As the frequency is very high, it means that it can be transferred through barrier materials like clothing and ceramics, which enables the ability to detect hidden explosives.

3 METHODS

3.1 Apparatus

To complete this experiment we used a Bunsen burner set to a blue flame (switched to safety orange when not performing observations), a heat resistant mat, a Nicrome wire, 1 mole solutions of unknown metal salts labelled A-H, a beaker with deionised water, and blue cobalt glass.

3.2 Procedure

Procedure as dictated from the data sheet provided for this experiment:
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 that the safety flame is on when the Bunsen burner is not in use.
2. To clean the wire of any residual contaminants, dip into 1 M deionised water and heat it in the hottest part of the flame, repeat until no colour is shown from the flame.
3. Cool the wire and dip into a solution, Heat the wire in the hot part of the flame. Record observations in the data table provided. Use the blue cobalt glass to determine the mixture of sodium and potassium (This is because the glass will filter yellow light from the solution).
5. Repeat for the other samples.

4 RESULTS

The results gained from this experiment are challenging to be given as absolutes due to individuals perceiving colours differently meaning that even myself and Tom Volpato could not 100 percent agree on the results of our own experiment. Referring to 2 it can be seen that multiple decisions were made to discern the colour of the flame this clearly shows the flaws in this form of experiment as it is completely based upon human judgement which invites ambiguity and incorrect assumptions.

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DATA SHEET TO RECORD OBSERVATIONS, CALCULATIONS AND RESULTS

date 02/06/23

STUDENT'S NAME: Alex Halliday / Tom Valpato

Observations and Identification:

(5p) Complete the table below. Based on the observed colour of the flame and Table 1, identify the metal ion in each unknown salt. Using the electromagnetic spectrum in Fig 2, estimate and report with the appropriate unit the wavelength for each observed colour. Identify the solution containing mixture of sodium and potassium:

Unknown metal salt	Colour of the flame	Identity of metal	Wavelength
DI water	orange	-----	-----
1 M HCl	-----	-----	-----
A	~~Red~~ orange Red N/A (Yellow/Green)	inconclusive Lithium	-----
B	Red/Pink	Strontium	-----
C	orange orange	Calcium	-----
D	violet	Barium	-----
E	Yellow	Sodium	-----
F	Yellow Red	Barium	-----
G	N/A	Citrium	-----
H	Green / blue Green	Copper	-----
I	Orange lavender	Potassium	-----

If in doubts refer to literature/youtube/etc

Fig. 2. Test results and observations

5 DISCUSSION

5.1 Analysis

After the experiment was concluded the other students and I fell into discussing the results. Due to the aforementioned ambiguity between observations, almost all of the results produced were different in minor ways, not drastically but enough to warrant the necessity of further testing and research to ascertain more concrete evidence. However, an overwhelming majority agreed that solution A requires more research as observations were inconclusive. This further research could be achieved on a high level spectrometer² which takes light, separates it by wavelength and creates a spectra which shows the relative intensity of these separate wavelengths. Using the visible light spectrum we can calculate the energies of some of the given colours. To work this out we must use the equation $E = h \cdot f$ to work out the equations of the photons. firstly we need to know the wavelength of the colour we are calculating for example orange has thw wavelength of 600nm. We can substitute this into the equation

$$(6.626 \cdot 10^{-34}) \cdot 600 = 3.9756 \cdot 10^{-31} \text{ Joules}$$

So by using this method we can work out the energy of the yellow flame

$$(6.626 \cdot 10^{-34}) \cdot 580 = 3.84308 \cdot 10^{-31}$$

and finally for the purple flame

$$(6.626 \cdot 10^{-34}) \cdot 380 = 2.51788 \cdot 10^{-31}$$

5.2 Validation

As shown by the data sheet in 2 Tom and I conducted multiple tests of the same solution to verify that the colours of the flame were - if not the same then similar. We also conducted the tests under a control banner of using

the blue cobalt glass to gather as much evidence as possible to make a decision on the overall metal salt in the solution. After conducting a basal test of the deionised water (which was orange showing no contaminants) we could gather observations and research of the other solutions. Solution A we decided was inconclusive as the flame very quickly changed colour after the solution was introduced to the flame hence an accurate identity could not be given, it was decided that more research and testing would be required to make an accurate assumption. Solution B gave a red/pink flame through the eye but a red flame through the glass, identified as Strontium. Solution C gave an orange flame through both the eye and the glass this was identified as Calcium. Solution D showed a Violet flame both through the glass this was another solution that was under great discussion as my other peers saw different colours, this was identified as Barium under process of elimination. Solution E gave a strong yellow flame indicating that it contained Sodium salts. Solution F gave off a ruby red colour suggesting Lithium was present, however due to limitations it is possible that Solution A and B could be opposites, again further testing would be required. Solution G showed a green/blue flame through the eye and just green through the glass, implying that Copper salts were present in the solution. Solution H through the eye showed orange, however through the glass the flame was lavender, meaning that Solution H was the mix of Sodium and Potassium. The blue cobalt glass absorbs yellow light and allowed us to witness the lavender flame.

6 CONCLUSION

We can see that Flame Tests are not suitable for higher level analysis of electromagnetic spectra, however they do have a place at a lower level to introduce this area of research in a cheap and accessible way. It can explain and provide a practical application to the theory of spectroscopy. It does highlight the inherent inability to make accurate observations as there are many more variables that can affect the results given, but this does mean that student can analyse the ways in which this process can be improved to give better results.

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