



James Burton

Lab Report 1 – Flame Test - Identifying Metal Ions Relevant to
Pyrotechnic Compositions

University of Wales, Trinity St Davids
Ordnance, Munitions and Explosives(Beng) - Chemistry

Academic Year: 2024 - 2025

Supervisor: Ewa Kazmierski
Associate Supervisor: Mark Broadhead

Table of Contents

1 Introduction.....	1
2 Results	2
2.1 Observations and identification	2
2.2 Key Findings and Patterns Observed	3
3 Discussion.....	5
3.1 Significance of Results.....	5
3.2 Comparison of Elements.....	5
3.3 Relevance to OME.....	5
3.4 Applications of Spectrometry Analysis	6
3.5 Limitations and Sources of Error.....	6
4 Conclusions.....	7
4.1 Summary and Evaluation	7
4.2 Future direction	7
5 References	8
6 Appendices.....	9
6.1 Appendix 1 – Materials and methods.....	9
6.1.1 Materials and equipment	9
6.1.2 Experimental procedure	9
6.1.3 Use of Cobalt Glass	10
6.2 Appendix 2 – Original Data Sheet.....	10

List of Tables

Table 1 - Recorded Observed Results	2
---	---

List of Equations

Equation 1 - Relationship between Frequency, Wavelength and The Speed of Light.....	1
Equation 2 - How to Calculate the Change in Energy Using Frequency and Plancks Constant.....	1

List of figures

Figure 1 - Visible Light Spectrum	2
Figure 2 - Chart of Wavelength Comparison	3
Figure 3 - Periodic Table of Elements	4

1 Introduction

The purpose of this experiment is to identify unknown metal ions using a flame test, observing their colour output and comparing it to the emission spectrum to understand the wavelengths of light which produce different colours during deflagration of materials.

The expectation is that each metal ion salt which is burned will produce a visibly different colour, which can be compared to the emission spectrum and an associated wavelength can be identified.

A dependant variable included in this report include wavelengths/colours emitted, from the burning of each of the metal salt ions, which translate into frequencies and therefore energy emittance. This is represented by the following equations:

$$f = \frac{c}{\lambda}$$

Equation 1 - Relationship between Frequency, Wavelength and The Speed of Light

Which can be used to identify the change in energy using the equation:

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

Equation 2 - How to Calculate the Change in Energy Using Frequency and Plancks Constant

Where:

f is the frequency of light in Hz^{-1}

c is the constant speed of light ($3.0 \times 10^8 \text{ms}^{-1}$)

λ is the wavelength(m)

h is a Planck constant ($6.63 \times 10^{-34} \text{Js}$)

ΔE is the change in energy level produced by the emittance of photons

2 Results

2.1 Observations and identification

For the experiment the following table was used to record findings, where the identified metals were assumed from the observations made in the following table:

Unknown metal salt	Colour of the flame	Identity of metal	Wavelength (nm)
DI water	Light Yellow	-----	-----
1 M HCl	Light Yellow	-----	-----
A	Orange	Sodium	610
B	Lilac	Potassium	405
C	Dark Orange	Calcium	640
D	Red/Pink	Lithium	680
E	Blue/Green	Copper	480
F	Dark Red	Strontium	750
G	Yellow/Green	Barium	560
H	Orange/Yellow	Mix	590

Table 1 - Recorded Observed Results [1]

The associated wavelengths recorded in the table are estimations based on the following scale:

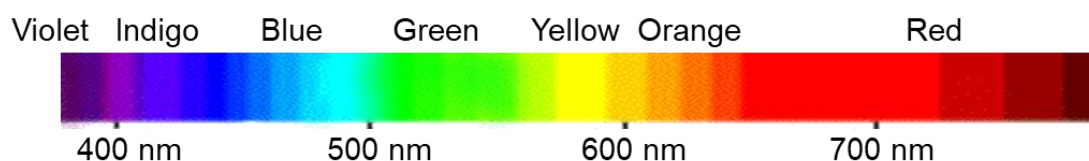


Figure 1 - Visible Light Spectrum [1]

2.2 Key Findings and Patterns Observed

The key findings identified during this experiment were the visible difference between colours emitted, which distinguishes obvious differences in wavelengths of photons emitted during the test, and therefore distinctive differences in changes of energy. There were no discernible patterns when analysing the data recorded in *table 1*. This will be discussed later in the report.

For visual referencing a chart has been created, listing the elements in order of how they appear in the periodic table (with the exception of the mixed compound):

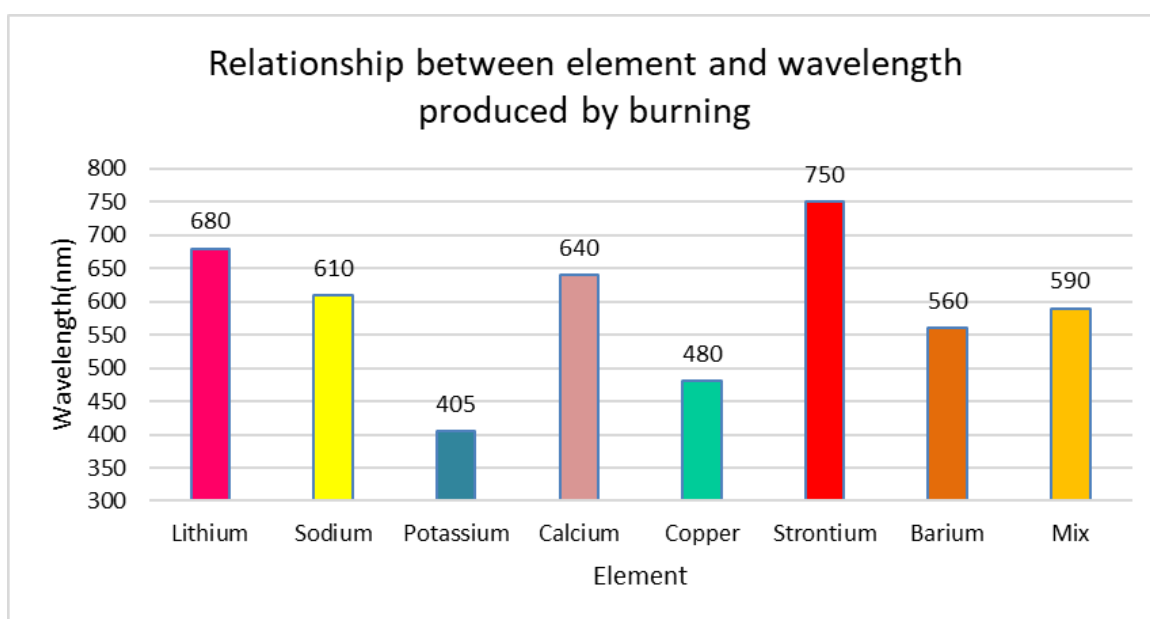


Figure 2 - Chart of Wavelength Comparison

1	1																18	
1A																	VIIIA	
1																	2	
H Hydrogen 1.00794																	He Helium 4.002602	
3	4											13	14	15	16	17		
Li Lithium 6.941	Be Beryllium 9.012182											III A	IV A	V A	VI A	VII A		
5	6											5	6	7	8	9	10	
Li Lithium 6.941	Be Beryllium 9.012182											B Boron 10.811	C Carbon 12.011	N Nitrogen 14.0067	O Oxygen 15.9994	F Fluorine 18.9984032	Ne Neon 20.1797	
11	12											13	14	15	16	17	18	
Na Sodium 22.98976928	Mg Magnesium 24.305											Al Aluminum 26.9815386	Si Silicon 28.0855	P Phosphorus 30.973762	S Sulfur 32.065	Cl Chlorine 35.453	Ar Argon 39.948	
19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	
K Potassium 39.0983	Ca Calcium 40.078	Sc Scandium 44.955912	Ti Titanium 47.88	V Vanadium 50.9415	Cr Chromium 51.9961	Mn Manganese 54.938045	Fe Iron 55.845	Co Cobalt 58.933195	Ni Nickel 58.6934	Cu Copper 63.546	Zn Zinc 65.38	Ga Gallium 69.723	Ge Germanium 72.64	As Arsenic 74.9216	Se Selenium 78.96	Br Bromine 79.904	Kr Krypton 83.798	
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	
Rb Rubidium 85.4678	Sr Strontium 87.62	Y Yttrium 88.90585	Zr Zirconium 91.224	Nb Niobium 92.90638	Mo Molybdenum 95.94	Tc Technetium [98]	Ru Ruthenium 101.07	Rh Rhodium 102.9055	Pd Palladium 106.42	Ag Silver 107.8682	Cd Cadmium 112.411	In Indium 114.818	Sn Tin 118.710	Sb Antimony 121.757	Te Tellurium 127.6	I Iodine 126.90447	Xe Xenon 131.29	
55	56	57-71		72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
Cs Cesium 132.90545196	Ba Barium 137.327	Lanthanoids		Hf Hafnium 178.49	Ta Tantalum 180.9479	W Tungsten 183.84	Re Rhenium 186.207	Os Osmium 190.23	Ir Iridium 192.222	Pt Platinum 195.084	Au Gold 196.966569	Hg Mercury 200.59	Tl Thallium 204.3833	Pb Lead 207.2	Bi Bismuth 208.9804	Po Polonium [209]	At Astatine [210]	Rn Radon [222]
87	88	89-103		104	105	106	107	108	109	110	111	112	113	114	115	116	117	118
Fr Francium [223]	Ra Radium [226]	Actinoids		Rf Rutherfordium [261]	Db Dubnium [266]	Sg Seaborgium [271]	Bh Bohrium [272]	Hs Hassium [278]	Mt Meitnerium [276]	Ds Darmstadtium [281]	Rg Roentgenium [288]	Cn Copernicium [285]	Nh Nihonium [286]	Fl Flerovium [289]	Mc Moscovium [290]	Lv Livermorium [293]	Ts Tennessine [294]	Og Oganesson [294]
57	58	59	60	61	62	63	64	65	66	67	68	69	70	71				
La Lanthanum 138.9047	Ce Cerium 140.12	Pr Praseodymium 140.90768	Nd Neodymium 144.24	Pm Promethium [145]	Sm Samarium 150.36	Eu Europium 151.964	Gd Gadolinium 157.25	Tb Terbium 158.92535	Dy Dysprosium 162.5	Ho Holmium 164.93032	Er Erbium 167.259	Tm Thulium 168.934	Yb Ytterbium 173.054	Lu Lutetium 174.967				
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103				
Ac Actinium [227]	Th Thorium 232.0377	Pa Protactinium 231.03688	U Uranium 238.02891	Np Neptunium [237]	Pu Plutonium [244]	Am Americium [243]	Cm Curium [247]	Bk Berkelium [247]	Cf Californium [251]	Es Einsteinium [252]	Fm Fermium [257]	Md Mendelevium [258]	No Nobelium [259]	Lr Lawrencium [262]				

4

3 Discussion

3.1 Significance of Results

The results obtained during the experiment signified the difference levels of energy produced, in the form of photons, differentiated by their wavelengths. This allows better understanding of how to identify material composition based on visual analysis.

3.2 Comparison of Elements

When comparing the results of copper and strontium, the frequency was first calculated, following by the change in energy when burned.

For Strontium:

$$f = \frac{3.0 \times 10^8}{750 \times 10^{-9}} = 4.0 \times 10^{14} \text{ Hz}$$

$$\Delta E = (6.63 \times 10^{-34}) \times (4 \times 10^{14}) = 2.65 \times 10^{-19} \text{ J}$$

For Copper:

$$f = \frac{3.0 \times 10^8}{480 \times 10^{-9}} = 6.3 \times 10^{14} \text{ Hz}$$

$$\Delta E = (6.63 \times 10^{-34}) \times (6.3 \times 10^{14}) = 4.14 \times 10^{-19} \text{ J}$$

It can be discerned from these calculations that a lower wavelength results in a higher frequency, and in turn there is a higher change in energy. This is likely due to copper being a more stable substance, having more of its electron shell filled, and therefore requires a higher energy input to excite the electrons into a higher state, therefore when they return back to the ground state they release a larger quantity of energy in the form of photons.

3.3 Relevance to OME

With regards to OME, a more advanced method called spectroscopy is used, where a Fourier-Transform InfraRed (FTIR) spectrometer is used to collect high-resolution spectral data of a wide spectral range, enabling analysts to identify

chemicals and verifying the use of substances such as Semtex, dynamite, TNT and hundreds of other coloured materials.[3]

3.4 Applications of Spectrometry Analysis

Other applications of Spectrometry analysis include pesticide screening, soil contamination, drug discovery and absorption, carbon dioxide monitoring and many other things.[4]

3.5 Limitations and Sources of Error

Limitations for this experiment were as follows:

- Cleanliness of equipment causing potential contamination – particularly using the same metal rod across all salts, even though it was cleaned it cannot be guaranteed that it was clear of contamination
- Using only visual analysis

Both of these variables could lead to errors when attempting to identify colours and associated wavelengths.

4 Conclusions

4.1 Summary and Evaluation

In summary, different elements can be identified by the input of energy and observation and analysis of light colour output, comparing it to a wavelength spectrum. It can also be said that the longer the wavelength, the lower the frequency and therefore the lower the change in energy. The difference in colour output observed during this experiment supports the hypothesis stated in the introduction.

4.2 Future direction

Considering the limitations and potential errors, if this experiment were to be conducted again it could be improved using separate, clean metal rods for each substance burned, as well as a spectroscope to analyse the colour/wavelength of photon emission for more accurate results.

5 References

- [1] University of Wales Trinity Saint David. ND. *ACDB 4011: Flame Test*.
- [2] Foxx Life Sciences. 2025C. *Periodic Table of Elements*. Available at: <https://www.foxxlifesciences.com/pages/periodic-table-of-elements-chart>. Accessed 20250302.
- [3] L.Tuhut, L.Munteanu, A.Simon-Marinica, A.Matei. 2022. *Explosives Identification by Infrared Spectrometry*. Available at: https://www.matec-conferences.org/articles/matecconf/pdf/2022/20/matecconf_simpro2022_00025.pdf. Accessed 20240302.
- [4] Thermofisher Scientific. 2025. *Mass Spectrometry Application Areas*. Available at: <https://www.thermofisher.com/uk/en/home/industrial/mass-spectrometry/mass-spectrometry-learning-center/mass-spectrometry-applications-area.html#:~:text=Specific%20applications%20of%20mass%20spectrometry,proteins%20identification%2C%20and%20carbon%20dating>. Accessed 20250302.
- [5] Libretexts Chemistry. ND. *Flame Test*. Available at: [https://chem.libretexts.org/Courses/Hope_College/General_Chemistry_Labs/Pre-Lab_Materials/Flame_Test#:~:text=Cobalt%20glass%20\(Co\(s\)\),the%20sample%20into%20the%20flame](https://chem.libretexts.org/Courses/Hope_College/General_Chemistry_Labs/Pre-Lab_Materials/Flame_Test#:~:text=Cobalt%20glass%20(Co(s)),the%20sample%20into%20the%20flame). Accessed 20250302.

6 Appendices

6.1 Appendix 1 – Materials and methods

6.1.1 Materials and equipment

The following equipment was used during the experiment:

- Bunsen burner
- Heat-resistance mat
- Matches
- Metal rod
- 1M solutions of unknown metal salts labelled A-H
- Beaker with 1M Hydrochloric Acid (HCL)
- Beaker with deionised water (DI water)
- Blue cobalt glass

6.1.2 Experimental procedure

1. A Bunsen burner was set up on the surface of the heat-resistant mat. It was then lit and the air vent to opened to obtain a non-luminous flame with two blue cones. When the Bunsen burner was not in use, it was ensured that the safety yellow flame was on.
2. The wire was cleaned by dipping it into the 1M HCl and then heated in the hottest part of the flame. This step was repeated several times until no colour was shown. If the flame's colour changed, there was still an impurity on the wire and it was dipped again in the acid and returned it to the flame until the wire is clean.
3. The wire was then dipped in DI water and heated as before to remove any residue of HCl from the cleaning step. Steps 3 and 4 were repeated before/after each test.
4. The wire was then allowed to cool and dipped in the solution of one of the unknown metal salt/mixtures. The wire was then heated in the hot part of the flame an observation of the coloured flame was recorded in the table. Cobalt glass was used to identify the mixture of sodium and potassium.

5. Steps 2-4 were repeated for all other unknown samples.
6. the colour of the flame for DI water and 1 M HCl was also recorded for reference.

6.1.3 Use of Cobalt Glass

Blue cobalt glass was used during this experiment to remove yellow(sodium) emission, to identify elements which weakly emitted blue and/or violet.[5]

6.2 Appendix 2 – Original Data Sheet

University of Wales Trinity Saint David – OME Programme

DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS

STUDENT'S NAME: James Bullen

PARTNERS' NAMES: Joseph Nelums + Thomas Cresswell

REPORT IS DUE MARCH 14th (21st with DD), 2025 submitted via Moodle

Observations and Identification:

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	light yellow	-----	-----
1 M HCl	light yellow	-----	-----
A	orange orange	~~Sodium~~ Sodium	610 nm
B	lavender lavender	Potassium	405 nm
C	dark orange dark orange	Calcium	630-640 nm
D	Red/pink Red/pink	~~Strontium~~ Lithium	680-690 nm ✓
E	green blue green	Copper	480-490 nm
F	dark red dark red	Strontium	660-670 nm ✓
G	light blue yellow/green	~~Barium~~ Sodium/Copper	560 nm
H	orange orange	Sodium mixture	500-630 nm

5