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Chemistry Lab Report 1 – Flame Spectroscopy

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Academic integrity declaration

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- the thesis submitted has been written by me alone.
- the thesis submitted has not been previously submitted to this university or any other.
- that all content, including primary and/or secondary data, is true to the best of my knowledge.
- that all quotations and references have been duly acknowledged according to the requirements of academic research.

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Acknowledgements

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List of Abbreviations

FTIR	Fourier transform infrared spectroscopy
OME	Ordnance Munitions & Explosives

1. Introduction

1.1. Aim of experiment

The purpose of this experiment is to determine which unknown metal salts were present in a series of eight different solutions as well as provide experience in lab protocol, techniques and report writing.

1.2. Hypothesis

The hypothesis being tested in this experiment is that the metal salts can be determined by heating the solutions in a flame, identifying the colour produced, and therefore wavelength of the light emitted. This wavelength can then be compared with the existing data on the wavelengths of light produced by metal salts and the student can then determine what salts are present through comparison.

1.3. Experiment variables

Independent variable:

Solution tested and therefore the metal salts present in each solution.

Dependant variable:

Colour of the flame produced by the heated solution.

Control variables:

- Flame type: Bunsen burner.
- Lighting conditions: Ease of viewing flame.
- Ambient temperature: Constant room temperature.
- Cleaning solution: 2M HCl, Deionised water.
- Inoculation loop material

1.4. Experiment equations

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

f = frequency (Hz)

λ = Wavelength (m)

c = Speed of Light constant ($3.0 \times 10^8 \text{ ms}^{-1}$)

Equation 1 - Relationship between speed of light, wavelength and frequency

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

f = frequency (Hz)

h = Planck's Constant (6.63×10^{-34})

ΔE = Difference in energy levels (J)

Equation 2 - Relationship between change in energy, Planck's constant and frequency

2. Results

2.1. Results

In the experiment all the solutions produced a coloured flame when burned. The different colours observed by the student are listed alongside an estimation of which metal ions are present in the solute. An additional estimation of the observed wavelength is also recorded, using Figure 1 as a reference.

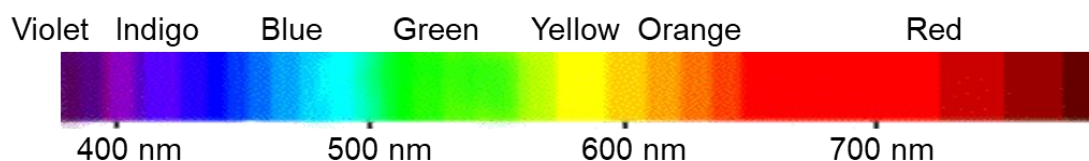


Figure 1 - Visible Light Spectrum [1]

Unknown Metal Salt	Flame colour	Metal identity	Wavelength (nm)
DI Water	Yellow	N/A	N/A
2M HCl	Yellow	N/A	N/A
A	Orange	Na	610 - 620
B	Lilac	K	400 - 410
C	Dark Orange	Ca	630 - 640
D	Red	Sr	690 - 700
E	Blue Green	Cu	480 - 490
F	Pink, Red	Li	670 - 680
G	Yellow Green	Ba	555 - 565
H	Yellow Orange	Na	610 - 620

Table 1 - Results from experiment

The mixture solution was narrowed down to samples A and H however the additional colours present in the flame were not able to be observed even with the cobalt glass. This is present due to contamination from the Sodium salts as they produce a bright Yellow/Orange flame which drowns out the other salts light emission. No patterns in the data were apparent to the student as even though some of these elements share similar locations on the periodic table, they would still produce a variety of colours.

H 1	Periodic Table																He 2
Li 3	Be 4	The Royal Society of Chemistry's interactive periodic table features history, alchemy, podcasts, videos, and data trends across the periodic table. Click the tabs at the top to explore each section. Use the buttons above to change your view of the periodic table and view Murray Robertson's stunning Visual Elements artwork. Click each element to read detailed information.										B 5	C 6	N 7	O 8	F 9	Ne 10
Na 11	Mg 12											Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54
Cs 55	Ba 56	La 57	Hf 72	Ta 73	W 74	Re 75	Os 76	Ir 77	Pt 78	Au 79	Hg 80	Tl 81	Pb 82	Bi 83	Po 84	At 85	Rn 86
Fr 87	Ra 88	Ac 89	Rf 104	Db 105	Sg 106	Bh 107	Hs 108	Mt 109	Ds 110	Rg 111	Cn 112	Nh 113	Fl 114	Mc 115	Lv 116	Ts 117	Og 118
		Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71		
		Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103		

Figure 2 - Periodic table [2]

3. Discussion

3.1. Significance of results

Even though the metal ions were from the same groups, they would still vary in colour produced due to the difference in gaps between energy levels. This is due to the difference in proton count as well as the number of electron shells. An increase in the proton count will increase the electrostatic force however the increase of electron shells dampens this force through electron shielding. The shorter the wavelength observed, the higher the energy between energy levels in the metal. The flame colours are produced by the emission of photons from the electrons in the metal moving between energy levels.

3.2. Metal salt comparison

When comparing the wavelengths produced by lithium and potassium in Figure 1, the difference in energy gaps between the energy levels in the metals can be determined through the following calculations:

Calculation of frequency (Hz):

$$f_K = 3 \times 10^8 / \lambda_K = 3 \times 10^8 / 405 \times 10^{-9} = 7.41 \times 10^{14} \text{ Hz}$$

$$f_{Li} = 3 \times 10^8 / \lambda_{Li} = 3 \times 10^8 / 675 \times 10^{-9} = 4.44 \times 10^{14} \text{ Hz}$$

Calculation of energy gap (J):

$$\Delta E \text{ (J)} = 6.63 \times 10^{-34} \times f \text{ (Hz)}$$

$$\Delta E_K = 6.63 \times 10^{-34} \times 7.41 \times 10^{14} = 4.91 \times 10^{-19} \text{ J}$$

$$\Delta E_{Li} = 6.63 \times 10^{-34} \times 4.44 \times 10^{14} = 2.94 \times 10^{-19} \text{ J}$$

Using the above calculations, potassium has an energy gap 1.67 times greater than lithium.

3.3. Relevance to OME

The use of spectroscopy is relevant in the OME field as explosive compounds can be identified. One of these techniques is called Fourier transform infrared spectroscopy (FTIR). This process can identify, and discriminate explosives based on their characteristic fingerprint spectra, not only as pure crystalline forms but also in real post-blast forms [3]. This technique works by measuring the absorption of light by the sample when a light is shined on it. This light will contain multiple wavelengths of light and then an absorption spectrum is produced and can be compared to determine the explosive.

3.4. Application of spectroscopy

Another application of spectroscopy is its use in Phytochemistry, which is the study of bioactive compounds extracted from plants. [4]

3.5. Sources of error

The method of this experiment allowed for a range of error sources:

1. Use of the same inoculation loop – Allowed for contamination from both previous experiments and the current experiment. This would be fixed by ensuring that you use a fresh loop for each sample.
2. Dipping of loop in sample – The sample would be contaminated with any remnants left from both the student's group as well as the other groups in the lab. This could be resolved by transferring the main sample into containers for each group, reducing cross-contamination.
3. Human error – When determining the wavelength of light, the method relied on human observation along with a comparison against a printed chart to estimate the wavelength of light. This could be made more accurate using equipment to measure the wavelength instead.

4. Conclusions

The results of the experiment validated the hypothesis of the experiment, the different salts were determined with exception of the mix. Each of these salts produced different wavelengths of light and direction for further experimentation

could be to test a wider variety of metal salts to determine if a wider pattern can be observed

5. References

- [1] University of Wales Trinity Saint David, *ACDB 4011: FLAME TEST*, Swansea, ND.
- [2] Royal Society of Chemistry, Royal Society of Chemistry, 2025. [Online]. Available: <https://periodic-table.rsc.org/>. [Accessed 07 03 2025].
- [3] ELSEVIER, "Post-blast detection of traces of explosives by means of Fourier transform," *Vibrational Spectroscopy*, vol. 51, no. 2, pp. 168-176, 2009.
- [4] K. P. Ingle, "Phytochemicals: Extraction methods, identification and detection of bioactive compounds from plant extracts.," *Journal of Pharmacognosy and Phytochemistry*, vol. 6, no. 1, pp. 32-36, 2017.
- [5] T. Cresswell, *DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS*, Swansea, 2025.

6. Appendices

6.a. Annex a - Materials and methods

Lab tools and supplies:

- Bunsen burner
- Heat-resistant mat
- Matches
- Metal inoculation loop
- 1 M solutions of unknown metal salts labelled A-H
- Beaker with 2 M HCL
- Beaker with deionised water
- Blue cobalt glass

Procedure [1]:

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 yellow flame is on when the Bunsen burner is not in use.
2. To clean the wire, dip it into the 2M HCl and heat it in the hottest part of the flame. This step is usually repeated several times until no colour is shown. If the flame's colour changes, there is still an impurity on the wire. Dip it again in the acid and return it to the flame until the wire is clean.
3. Dip the wire in deionised water and heat as before to remove any residue of HCl from the cleaning step. Repeat steps 3 and 4 before/after each test!
4. Cool down the wire and dip it in the solution of an unknown metal salt/mixture. Heat the wire in the hot part of the flame. Record your observation of the coloured flame in the table below. Use the cobalt glass to identify the mixture.
5. Repeat steps 2-4 for all other unknown samples.
6. Record the colour of the flame for DI water and 2 M HCl.

Explanation of cobalt glass

The use of cobalt glass in this experiment is due to the wavelength filtering properties the glass has. Sodium has a very strong flame when burning which can obscure the light emitted by other salts present in the mixture if any. The cobalt glass absorbs these wavelengths of light making it easier for the human eye to determine any other salts present in the flame.

6.b. Annex b – Original data sheet [5]

University of Wales Trinity Saint David – OME Programme

DATA SHEET to RECORD OBSERVATIONS, CALCULATIONS and RESULTS

STUDENT'S NAME: THOMAS CRESSWELL

PARTNERS' NAMES: JOSEPH NEUMANS + JAMES BURTON

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	Yellow	Yellow	-----
1 M HCl	Yellow	Yellow	-----
A C	Dark a Red?	Dark O.	Ca ²⁺ 630-640 nm 635 nm
B	Lilac	Lilac	K 405 nm
A	Orange	Orange	Na 615 nm
D	Red	Red	~~Sr~~ Sr 690-700 nm
E	Blue Green	Blue green	Cu 480-490 nm
F	Dark red	Pink red	~~Li~~ Li 670-680 nm
G	Yellow green	Yellow green	~~Barium~~ Barium 560 nm
H	Yellow Orange	Yellow Orange	Na mix 615 nm

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