

Flame test lab report

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Introduction

The purpose of this experiment was to identify the metal ions present in 8 unknown solutions; this was done by conducting a flame test and observing the different colours which were emitted. It was hypothesised that each solution will emit a different colour when vapourised in the flame, this is due to the metal ion absorbing energy from the flame, causing one of its outer electrons to move to a higher energy level. This excited state is unstable, when the excited electron returns to a lower energy level (its ground state), the absorbed energy is released as light. The wavelength of the light released is proportional to the energy released in the following relationship (give equations).

(Eq.1) [3]

$$c = f \times \lambda$$

(Eq.2) [3]

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

always explain the terms in an equation and provide units

The independent variable of this experiment is the metal salt, and the dependent variable is the colour of the flame as this will differ depending on the metal salt present in the unknown solution. It is also important to be aware of the following controlled variables which are required to be kept to the same to ensure that test is accurate; cleaning the metal wire between solutions to remove as much contamination as possible which will reduce the accuracy of identifying metal ions.

Results

Each of the unknown alkali metal solutions were heated in sequence as specified in the methodology in appendix 1 and the colour given off was recorded in table 1.

(Table 1)

Unknown metal salt	Colour of the flame	Identity of metal	Approx Wavelength
DI water	Orange	N/a	-----
2M HCL	Orange	N/a	-----
A	Orange/yellow	Sodium	590nm
B	Purple	Potassium	390nm
C	Red- orange through cobalt	Calcium	620nm
D	Dark red	Strontium	700nm
E	Green/ blue	Copper	490nm
F	Pink/ red	Lithium	640nm
G	Yellow/ Green	Barium	550nm

H	Orange, yellow / Purple through cobalt	Sodium/ Potassium	620nm/400nm
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all metal ions are correctly identified

From this experiment the metal ions which were present in the eight unknown solutions were identified. It was apparent that the identification of these metal ions can be subjective to the individual interpreting multiple samples. The wire was cleaned between solutions with ~~HCL~~^{HCl} before burning this off in the flame and removing the residue of ~~HCL~~^{HCl} by dipping the loop in deionised water before heating again- It was observed that a yellow orange flame was present for multiple samples which suggest the metal loop had become contaminated with sodium making it harder to correctly identify the metal ion which was present.

excellent observation

4. Discussion

A flame test is a qualitative method used to identify alkali metal compounds quickly without the requirement of sophisticated equipment.^{ref} This method is very useful for remote environments when access to resources is limited as it allows you to distinguish compounds which are present without the use of lots of equipment.

Different wavelengths are emitted when a solution is vapourised in the flame as each metal ion requires a different amount of energy to promote the electrons to a higher energy level orbital [figure 1]. The electron is unable to remain in this excited state and will quickly return to its grounded state, this process releases energy (photon) in the form of light.[1] The wavelength emitted by the metal ions can then be related to the electromagnetic spectra in terms of the approximate wavelength which would allow the frequency and the energy difference between energy levels to be calculated.

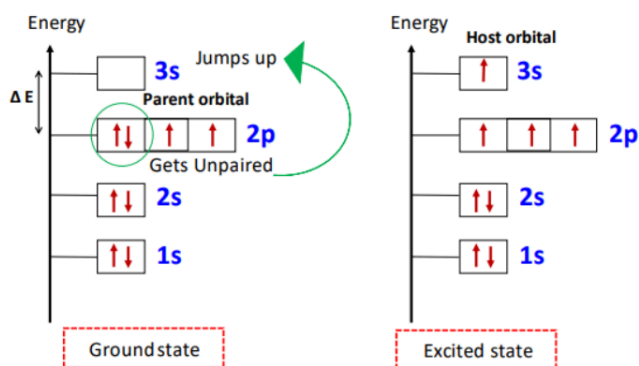


Figure 1: [2]

The metal ions emit unique wavelengths of visible light when the excited electrons return to its ground state, the visible colour that correspond to this specific wavelength and this can be used to calculate the frequency of emitted light, allowing the energy difference in orbitals to be calculated as the wavelength and lambda are inversely proportional.

wavelength and lambda represent the same thing

For sample B the metal ion which is present is potassium with an approximate wavelength of 390nm based of the purple colour observed from the flame can divided by the speed of light to determine the frequency of light in hertz. The frequency of light is then used to calculate the energy difference between the high and lower energy states.

(Eq.1) [3]

$$C = f \times \lambda$$

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

$$f = \frac{3.0 \times 10^8}{3.9 \times 10^{-9}} = 7.69 \times 10^{16} \text{ s}^{-1}$$

7.7 sig figs

C = speed of light $3.0 \times 10^8 \text{ Js}^{-1}$

Planck constant mixed up with speed of light

$f = \text{frequency}$

$\lambda = \text{wavelength}$

(Eq.2) [3]

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

$$\Delta E = 6.63 \times 10^{-34} \times 7.69 \times 10^{16} = 5.09847 \times 10^{-17} \text{ Js}$$

sig. figs.

H = planks constant

$$6.63 \times 10^{-34} \text{ Js}$$

For sample D the metal ion which is present is strontium with an approximate wavelength of 650nm based of dark red colour observed in them flame.

(Eq.1) [3]

$$C = f \times \lambda$$

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

$$f = \frac{3.0 \times 10^8}{6.5 \times 10^{-9}} = 4.6154 \times 10^{16} \text{ s}^{-1}$$

sig figs

C = speed of light $3.0 \times 10^8 \text{ Js}^{-1}$

$f = \text{frequency}$

$\lambda = \text{wavelength}$

(Eq.2)[3]

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

H = planks constant

$$6.63 \times 10^{-34} \text{ Js}$$

$$\Delta E = 6.63 \times 10^{-34} \times 4.6154 \times 10^{26} = 3.06 \times 10^{-7} \text{ Js}$$

The burning of metal salts is used in pyrotechnics as different metal salts emit different wavelengths of light. When different metal salts are combined with other components such as a binder, gun powder, oxidising agent and a time delays fuse and placed in an aerial shell.[4] When the fireworks explode mid-air and the electrons in the metal compound return from their excited state to their ground state this produces energy a display of various coloured light is displayed.

The use of pyrotechnics has military applications as this phenomenon is present signal flares and tracers- these are required to be visible from a considerable distance and in adverse environments such as bright sky for example.[7] Tracer ammunition has a small pyrotechnic attached to the base of the projectile which when ignited it burns in the cartridge casing giving of an extremely bright light.[5] This techniques was introduced to allow gunner to see the round that they were firing to increase precision and accuracy, they are also used to mark targets or establish a field of fire for other gunners, however this has its implications as this would also identify their position to the enemy force .[5] To combat this dark tracers were introduced which meant the pyrotechnic wouldn't burn at full capacity until a few hundred yards away which avoided giving away the gunners position and also stopped the person firing becoming dazzled by the colours when firing at night.[6]

One of the limitations of this experiment is that when determining the energy difference which is required to excite the electrons from its ground to excited state requires a precise frequency value- This means using approximate wavelength based on a visually observed colour with the naked eye reduces the level of accuracy of the calculation due to human error and this can also vary down to the interpretation of the individual.

Another limitation it is not possible to accurately determine the metal ions which are present in a mixture due there being a combination of colours which will be visible. This technique is useful for group 1 metals however this method identification will not be applicable to all metals and not all metals will produce colours when heated.

5. Conclusions

To conclude flame tests can be used to determine what metal ion is present in a solution when it is vaporised in a flame, due to different wavelengths of visible light being emitted from different metal ions we can identify the ions which are present in

the solution- which supports the proposed hypothesis. To improve this analytical technique in future the use of atomic emissions spectrometers which would allow the accurate identification and determinations of wavelengths from the unknown sample which would accurately determine the quantized energy between the different of the different states. The method use in this experiment relies on an individual's interpretation of the colour which is produced in the flame and then relating this to the electromagnetic spectrum with an estimate of its approximate wavelength, which will reduce the accuracy of calculating the energy difference in orbitals.

References

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7. Appendix: Materials and methods

Equipment and Materials used

- Bunsen burner
- Heat proof mat
- Metal rod
- 1M solution of unknown metal salts (labelled A-H)
- 2M HCL
- Deionised water (DI)
- Blue cobalt glass

Methodology

- Set up Bunsen burner on a heat proof mat and light it- Ensure air vent is open to produce non-luminous flame with two blue cones. (yellow safety flame when Bunsen burner is not in use).
- Ensure metal wire is cleaned with HCL and heated in the flame- repeat several times into no colour is shown/ impurity are removed.
- Dip the wire in DI water and heat to remove residue of HCL. Repeat above step between each solution.
- Allow wire to cool before dipping into unknown solution, heat the wire and record observation of colour emitted. Use cobalt glass to identify mixture of potassium and sodium. Repeat the above steps for all unknown samples. The use of cobalt glass was imperative in this experiment to improve the accuracy of identification of the metal compounds as a yellow flame was present in multiple samples due to the contamination of sodium, through the blue glass this allowed us to distinguish purple and blue flames.
- Record colour of flame with 1M HCL and DI.

53/100

GENERAL COMMENTS

Engagement with Literature Skills 8/15

A good mix of literature is used, but some sections lack supporting references, such as parts of the theoretical explanation. IEEE format is inconsistently applied, with citation errors and symbol misuse. While seven sources are cited, not all are peer-reviewed.

Feedback: Support all claims with appropriate references and ensure consistent IEEE formatting with authoritative sources.

Knowledge and Understanding Skills 11/20

The report presents an excellent hypothesis and correctly identifies variables. There is a very good explanation of the absorption-emission phenomenon, but terms in equations are not explained and units are missing. Planck's constant is confused with the speed of light, and symbols like λ and wavelength are used to represent different terms.

Feedback: Always define all equation terms with correct units and symbols (e.g., h for Planck constant).

Cognitive and Intellectual Skills 13/25

The application in flares and tracer rounds is recognised. Potential errors and method limitations are discussed, with solutions such as spectroscopy proposed. However, some conceptual points (e.g., symbol use) need clarity.

Feedback: Ensure accurate use of symbols and figures and critically validate numerical data.

Practical Application Skills 12/25

All metal ions are correctly identified. Wavelength estimates are mostly accurate, but errors in significant figures and symbol misuse are evident.

Feedback: Apply correct significant figures and scientific symbols, and reference methods within the main report.

Transferable Skills 9/15

The report includes clear structure, but lacks a Table of Contents. Writing is generally formal, though there are occasional grammar issues. Use of symbol inconsistencies reduce professionalism.

Feedback: Add a ToC, maintain passive voice, and proofread for technical accuracy.

Text Comment. there is no title page, ToC

Text Comment. always explain the terms in an equation and provide units

Text Comment. all metal ions are correctly identified

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