

## Recording emission spectra of a flame test

### Aims of the experiment

- To burn metal salts in the Bunsen burner flame
- To recognise that metal salts emit light of different colours
- To record the flame colourations in SpectraLab
- To gain information about the structure of matter from the flame colouration
- To use flame colouration in spectral analysis

### Principles

The salts of some metals, including particularly those of the alkali and alkaline earth metals, colour the non-glowing flame of a burner in characteristic colours. The yellow glow of sodium is particularly well-known here, which is also used in sodium vapour lamps.

Flame colouration is based on the following mechanism. Atoms are able to absorb energy, in this case from thermal excitation. Through the supplied energy, electrons jump from lower energy inner orbitals into higher energy outer orbitals. The atom is then in an excited state. This does not last for long. When the electrons jump back to their ground level, they emit the absorbed energy in the form of light. In this case, every electron emits a photon (a light particle).

The energy (and therefore the frequency and wavelength) of these photons depends on the energy of the electron. In the orbitals of an atom, electrons can only possess certain (= discrete) energies. Therefore only photons of a defined frequency can be emitted. In this way, every type of atom displays a characteristic emission spectrum. This property is used in so-called spectral analysis in order to characterise mixtures that contain different metals.

Coloured flames can be recognised with the eye. If a spectrometer is used, the spectral distribution in the emission spectrum can be resolved, and therefore mixtures of different metals differentiated.

A compact grating spectrometer will be used in this experiment. This measures simultaneously at all wavelengths. In this way, the relevant spectral lines can be made visible and recorded.

### Risk assessment

Some of the metal salts used are hazardous to health or toxic. Choose suitable salts according to the application! Caesium chloride, potassium chloride, sodium chloride and rubidium chloride are not classified as hazardous substances.

Wear protective goggles! Protect long hair against burning!



Fig. 1: Set-up of the experiment.

<b>Barium chloride</b>	
 <b>Signal word:</b> <b>Hazard</b>	<b>Hazard statements</b> H332 Harmful if inhaled. H301 Toxic if swallowed. <b>Precautionary statements</b> P301+P310 IF SWALLOWED: Immediately call a POISON CENTER or doctor/physician.
<b>Calcium chloride</b>	
 <b>Signal word:</b> <b>Caution</b>	<b>Hazard statements</b> H319 Causes serious eye irritation. <b>Precautionary statements</b> P305+P351+P338 IF IN EYES: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.
<b>Strontium chloride</b>	
 <b>Signal word:</b> <b>Caution</b>	<b>Hazard statements</b> H302 Harmful if swallowed.

Copper(II) nitrate	
	<p><b>Hazard statements</b></p> <p>H272 May intensify fire; oxidizer  H302 Harmful if swallowed.  H315 Causes skin irritation.  H319 Causes serious eye irritation.  H410 Very toxic to aquatic life with long-lasting effects.</p> <p><b>Precautionary statements</b></p> <p>P210 Keep away from heat. No smoking.  P273 Avoid release to the environment.  P302+P352 IF ON SKIN: Wash with soap and water.  P305+P351+P338 IF IN EYES: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.</p>
<p><b>Signal word:</b> Hazard</p>	
Lithium chloride	
	<p><b>Hazard statements</b></p> <p>H302 Harmful if swallowed.  H315 Causes skin irritation.  H319 Causes serious eye irritation.</p> <p><b>Precautionary statements</b></p> <p>P302+P352 IF ON SKIN: Wash with soap and water.  P305+P351+P338 IF IN EYES: Rinse continuously with water for several minutes. Remove contact lenses if present and easy to do. Continue rinsing.</p>
<p><b>Signal word:</b> Caution</p>	
Strontium chloride	
	<p><b>Hazard statements</b></p> <p>H302 Harmful if swallowed.</p>
<p><b>Signal word:</b> Caution</p>	

### Equipment and chemicals

1 Compact spectrometer USB, physics.....	467 251
1 Optical fibre holder .....	460 251
1 Saddle base .....	300 11
1 Gas igniter, mechanical.....	666 731
1 Micro powder spoon, stainless steel, 150 mm..	666 960
1 Spotting plate, 17 mm diam.....	667 089
1 Teclu burner, universal.....	656 017
1 Safety gas hose with clamp, 0.5 m.....	607 020
1 Magnesia rods, 25 pcs. ....	673 0840
1 Dropping pipette, 150 x 7 mm, set of 10.....	665 953
1 Rubber bulbs, (pipette bulbs) .....	665 954
1 Salts for flame tests, set of 9 .....	661 088
1 Hydrochloric acid, 0.1 mol/L, 500 mL .....	674 6950

Also required:

- PC with Windows XP, Vista, 7 or 8
- Gas connection

### Set-up and preparation of the experiment

Using the spoon, place a small amount (a few crystals) of the various salts each in one well of the spotting plate and label them. Wipe off the spoon thoroughly between the samples. Ensure that the samples are not accidentally mixed!

Even small traces of sodium salts colour the flame yellow and will hide any other emissions. For this reason, ensure absolute cleanliness in these experiments.

Place a rubber teat on the dropping pipette. Moisten each of the samples with 1 drop of hydrochloric acid. Place a few drops of hydrochloric acid onto an empty well of the spotting plate.

Fix the fibre holder in the saddle base such that it can measure at the height of the flame (see Fig. 1).

### Performing the experiment

- Light the burner and fully open the air supply.
- Start a new measurement with  and with  start the measurement.
- Open the "Offset I0" display. The spectrum shown will be subtracted as the background spectrum during further measurements.
- Change to the display "Intensity I1". The intensity is now at a value of 0 % in the entire spectral range.
- Dip a magnesia rod into hydrochloric acid and glow it out thoroughly in the burner flame.
- Using the still hot end, take up a few salt crystals from the spotting plate. Hold the magnesia rod in the burner flame and visually observe the flame colour.

No crystals must be allowed to fall into the burner!

7. Adjust the integration time directly or with  or  such that the intensity of the lines is at a maximum. If necessary, reposition the optical fibre to achieve maximum intensity.

8. Save the spectrum with .

*Note: To reduce the effect of noise, several individual spectra can be recorded and averaged (also with Offset and Reference). Alternatively, "Smoothing to 1 nm resolution" can be selected in the settings.*

9. Repeat the experiment with further salts. For this, either break off the contaminated tip of the old magnesia rod or use a new, clean magnesia rod.

The magnesia rod is very hot! If it is to be broken off, do this using the spoon on a fireproof surface.

## Observation

The flame shows a characteristic colouring for every salt. This results from the colour and intensity of the individual emission lines. The corresponding line spectra can be seen in SpectraLab. As an example, Fig. 2 shows the line spectra of the alkali metals.

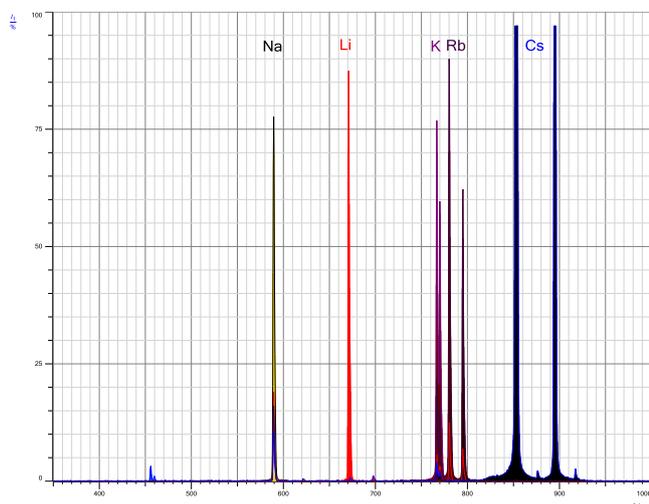


Fig. 2: Line spectra of the alkali metals.

## Evaluation

The colours of the flame colouring are based on the characteristic lines of the elements in the emission spectrum. The lines of the alkali metals are shown in Fig. 2. The flame colouring and wavelength of the most significant emission lines for the individual elements are summarised in Table 1.

As shown by the spectra of the individual example experiments, some elements also emit strong lines in the ultraviolet and infra-red range. For this reason, the colouring of caesium is barely visible to the eye, as the strongest lines appear in the infra-red region. The IR lines are highly visible in SpectraLab. The blue line of caesium at 458 nm is only weak, but can be recognised.

Contamination with sodium is frequently unavoidable. While the bright yellow sodium line slightly masks the weaker lines for the eye, these can be easily seen by the spectrometer, even in mixtures with sodium. This particularly applies to the colouring of potassium. It is difficult to observe by eye, as it is considerably weaker than sodium, for example. In practice, the sodium line is often filtered out with cobalt blue glass. In contrast, it shows little interference in the spectrum. The example spectrum (Fig. 2) also shows contamination with sodium in almost every sample.

Additionally, further samples such as plant ash, wood ash, table salt and similar substances can be investigated. In wood ash, a high content of potassium can be clearly seen. In addition, lines from sodium and rubidium are visible.

## Cleaning and disposal

Before washing the spotting plate, wipe it with a cloth to remove the salts. Dispose of the cloth in the container for inorganic solids.

Tab. 1: Flame colouring and wavelengths of the individual elements.

Element	Flame colouring, visual	Wavelengths of the most significant lines in nm
Calcium	brick-red	622.0 (red); 553.3 (green)
Caesium	blue	458.0 (blue); 852.1 (IR); 894.3 (IR)
Potassium	violet	786.3 (red); 404.4 (violet)
Lithium	red	670.8 (red)
Sodium	yellow	589.3 (yellow)
Rubidium	red-violet	780.0 (red); 794.8 (red); 420.0 (violet)
Strontium	carmin-red	604.5 (orange); 460.7 (blue); several red lines
Barium	green	524.2 (green); 513.7 (green)
Copper	green (in the presence of Cl) blue (pure copper nitrate)	510.5; 515.3; 521.8 (all green)