**Shadow of a Flame**

[Subtitle]

Absorption and Emission Spectrum

[Subject Symbol: Waves and Radiation]

[Icons]

Time

5 - 15 minutes

Scope:

Grade 5 and 6 VWO (pre-university education in the Netherlands)

Concepts: absorption spectra, emission spectra, formation of Fraunhofer lines, stellar atmospheres

[Opening Box]

This demonstration is highly suitable for clarifying the paradox surrounding the formation of absorption spectra: a gas indeed absorbs certain radiation, but then emits exactly the same wavelength. How then do the dark Fraunhofer lines arise? This demonstration clarifies that those lines arise due to scattering.

[End of Opening Box]

56\_WoS05\_SD\_foto1, onderschrift 1]

*De opstelling: een natriumlamp, een blauwe vlam en een half-doorlatend scherm (hier is een labjas gebruikt).*

[56\_WoS05\_SD\_foto3 en 56\_WoS05\_SD\_foto3, naast elkaar]

[Onderschrift 2 + 3; indien deze boven elkaar worden gezet ‘links’ veranderen in ‘boven’en ‘rechts’veranderen in ‘onder’]

*Links: de schaduw aan de andere kant van het scherm; rechts: de situatie met vlam. Hier is zowel de verstrooiing, de emissie en de resulterende absorptie zichtbaar.*

**Required**

Sodium lamp; burner; transparent screen large enough to conceal the flame from view; table salt (potassium salt can also be used); preferably a handheld spectroscope.

**Preparation**

The setup is best built in the classroom to emphasize the sequence of events: first emission, then absorption, then observation. Turn on the sodium lamp in advance or utilize the warm-up time by discussing why the lamp needs to warm up. The classroom should be darkened for maximum effect, but the phenomenon is also visible in a non-darkened classroom.

**Execution**

The teacher explains the setup and places the screen between the flame and the class, completely obscuring the flame from view. It is intended that the students first only see the shadow without being able to perceive the emission of the salt. Be mindful of reflective surfaces behind the flame (such as a whiteboard). By sprinkling table salt into the blue flame (see also tips), you can make the flame cast a clear shadow.

The didactic value lies primarily in the follow-up: the teacher asks for an explanation for the formation of the shadow, preferably with a schematic drawing of the setup and the process. You can also have the students predict the color of the flame. If desired, this can be done in multiple-choice form (transparent blue, opaque blue, transparent yellow, opaque yellow, transparent dark, opaque dark). Despite the fact that many students have seen sodium in a flame before, a reasonable number may choose 'opaque black' or 'opaque dark', apparently shadows are created by dark materials...

The setup can now be rotated 90 degrees to ask the result from nature itself. A number of students will be surprised when the flame becomes bright and opaque yellow. Now the class can together with the teacher come to the correct explanation and sketch.

The connection to the formation of the absorption spectrum in stellar atmospheres can now be quickly made.

**Physical Background**

The shadow arises because photons from the sodium lamp are scattered by the sodium in the flame. Photons are effectively absorbed by the sodium in the flame and then emitted again in a random direction. This causes the flame to be bright yellow in all directions. Only in the original direction of the photons are there fewer after the flame than before, while that effect does not occur for photons passing alongside the flame. We observe a shadow on the screen.

Note that the emission spectrum you observe in the flame consists partly of a true emission spectrum, because an electron will recombine with the sodium ion. The other part is a scattering spectrum, due to the absorption and re-emission of light from the sodium lamp.

**Tips**

Instead of sprinkling salt, you can also dip a paperclip bent into an eyelet and cleaned in a salt solution and hold it in the flame. You will have no mess this way.

**Further Research**

With a spectroscope, you can measure that the emission line of the lamp is the same as the emission line of the flame with table salt.

When using potassium salt, you will not get a shadow. You can first have the students predict this.

**Safety and Environment**

Small amounts of sodium oxide and sodium peroxide can be formed. Both are irritating.