

Qualitative investigation of the absorption spectrum of sodium.

Objects of the experiment

- Observation of the absorption of sodium light

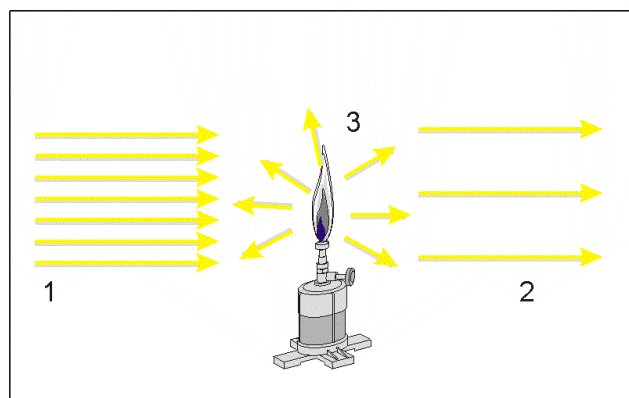


Fig. 1: Resonance fluorescence of sodium vapour schematically: The sodium atoms evaporated in the flame of a gas burner (3) absorb the light of a sodium lamp (1). The transmitted light (2) is reduced due to the absorption.

Principles

Quantum properties dominate the fields of atomic and molecular physics. The electromagnetic radiation and the energy levels of atoms and molecules can have only certain quantized values. Transitions between these quantized states occur by the photon processes absorption, emission, and stimulated emission.

When an electron in the shell of an atom or atomic ion drops from an excited state with the energy E_2 to a state of lower energy E_1 , a photon with the energy:

$$h \cdot \nu = E_2 - E_1 \quad (I)$$

ν : frequency of the photon

E_1 : energy of lower state

E_2 : energy of upper state

h : Planck's constant

is emitted. In the opposite case, if a photon with the same energy is absorbed by an atom an electron will be elevated from a state of lower energy E_1 to a state of higher energy E_2 .

The absorption or emission of a photon will occur only when the quantum energy of the photon matches precisely the energy gap between the initial and final states.

As the energies E_1 and E_2 of the participating pair of quantum energy states of an atom can only assume discrete values, the photons are only emitted and absorbed at discrete frequencies. The totality of the frequencies which occur is referred to as the spectrum of the atom. The positions of the spectral lines are characteristic of the corresponding element.

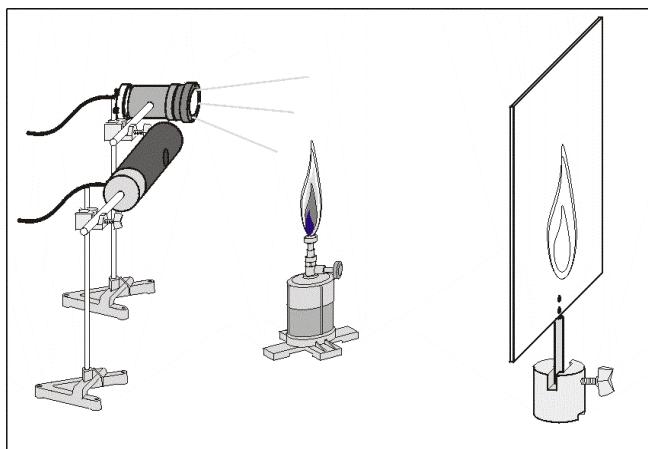
Optical spectra of atoms can be observed both in absorption and emission. In this experiment the flame of a Bunsen burner is alternately illuminated with white light and sodium light and observed on a screen. When sodium is burned in the flame, a dark shadow appears on the screen when illuminating with sodium light (Fig. 1). From this it is possible to conclude that the light emitted by a sodium lamp is absorbed by the sodium vapour, and that the same atomic levels are involved in both absorption and emission.

The sodium atoms which are excited by absorption in the flame reemitted light in all directions. The intensity of the reemitted light is very small in the direction of incidence.

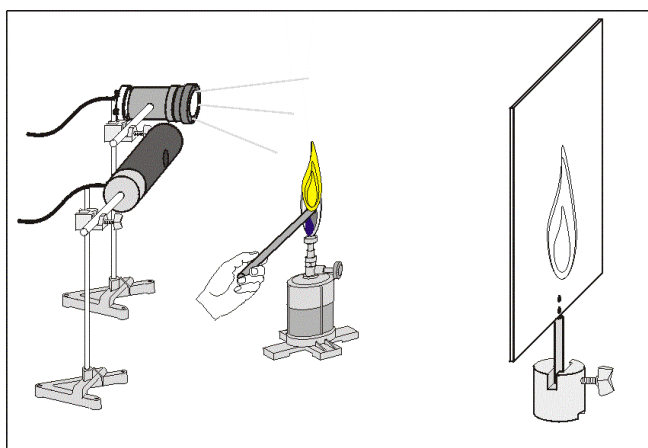
Apparatus

1 Housing for spectrum lamps.....	451 16
1 Spectrum lamp Na	451111
1 Universal choke.....	451 30
1 Lamp housing with cable.....	450 60
1 Incandescent lamp 6 V / 30 W	450 51
1 Transformer 6/12 V	521 210
1 Translucent screen.....	441 53
1 Saddle base	300 11
1 Butane gas burner.....	666 711
1 Butane cartridges, 190 g.....	666 712
2 Stand base, V-shape, 20 cm.....	300 02
2 Stand rod, 47 cm.....	300 42
2 Leybold multiclamp.....	301 01
1 Sodium chloride, 250 g.....	673 5700
1 Spatula, double ended, 150 x 9 mm.....	666 962
1 Magnesia rods, set of 25.....	673 0840

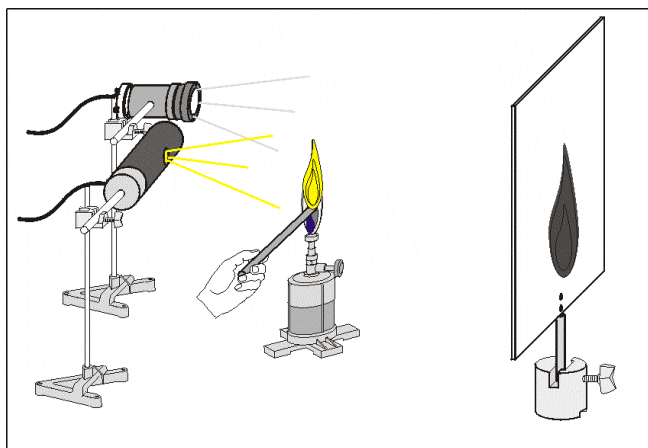
Fig. 2: Schematic sketch of the experimental setup for observing the absorption of sodium light by the sodium vapour in a flame of a gas burner:



Step 1: Using the white light the flame of a gas burner can be observed on the translucent screen (not a real shadow, only air streaking).



Step 2: Burning of sodium in the gas burner doesn't change the shadow of flame on the translucent screen (not a real shadow, only air streaking).



Step 3: Using the sodium lamp when burning sodium in the gas burner a dark shadow of the flame appears on the screen until the sodium lamp is switched off.

Setup

The setup of the experiment is shown in Fig. 1.

Set up the sodium lamp and the incandescent lamp for the white light opposite the translucent screen.

Place the gas burner between the lamps and the translucent screen.

Connect the housing for spectrum lamps (451 16) to the universal choke (451 30) and the lamp housing with cable (450 60) to the 6 V output of the transformer 6/12 V (521 210).

Carrying out the experiment

- Switch on the incandescent lamp and observe the flame of the gas burner on the translucent screen (not a real shadow, only air streaking), see Fig. 2, step 1.
- Put some sodium on the magnesia though (or dip a magnesia sticks into a sodium solution).
- Burning of sodium in the gas burner doesn't change the shadow of the flame on the translucent screen (Fig. 2, step 2).
- Switch on the sodium lamp and burn some sodium in the gas burner. A dark shadow of the gas burner will be cast on the translucent screen (Fig. 2. step 3). This shadow can be observed as long as the sodium lamp is not removed (or switched off).

Note: If a large quantity of sodium is allowed to evaporate in the flame the translucent screen will be illuminated more brightly by the sodium vapour than the sodium light. Therefore a dark shadow is only seen if the ratio of intensities is of the same order of magnitude.

Measuring example

The results of the various steps of the experiment are depicted in Fig. 2.

Evaluation and results

In the light of a sodium lamp a flame will cast a distinct shadow only if it contains some sodium vapour. The sodium atoms evaporated in the flame absorb the light of the sodium lamp just as they emit it. This equality of emission and absorption line is also apparent in the resonance fluorescence of sodium vapour. From this follows the conclusion that the same atomic energy states are involved in both absorption and emission.

Supplementary information

The yellow line of the sodium spectrum (which is a double line having the wavelength 589.0 nm and 589.6 nm, respectively) occurs in emission and in absorption spectra. Fraunhofer observed this line as an absorption line in the solar spectrum and called it the 'D-line'. Kirchhoff showed later on the basis of his radiation laws that this line must be due to the emission or absorption of sodium vapour. He indicated the experiment described above.

