Prelab Briefing and Worksheet

Who Shot the Gun?

Answer the questions posed in this prelab exercise on a separate sheet of paper. The questions are collected on the last sheet of this document. The completed prelab assignment is your ticket for admission to the lab. You won’t be allowed to do the lab without it.

Objective

In this experiment you will use a simple spectroscope to measure the wavelengths of the emission lines of hydrogen. The line spectrum will be used to draw an energy level diagram for hydrogen.

You will also determine the wavelengths of emission lines for barium, a trace element in gunpowder. You will match the wavelengths with the spectra for hand swab solutions taken from several “suspects” to determine who fired a gun.

Goals

1. Use a simple spectroscope to record line spectra.
2. Relate measured wavelengths with frequencies, photon energies, and energy level spacings.
3. Appreciate spectroscopy as a useful technique for “fingerprinting” chemical elements.

Required Reading


Background
Most substances will emit light when heated to high temperatures or subjected to a high electrical voltage. For example, iron emits light when it is "red hot". Mercury vapor in a street lamp glows when an electric current passes through the lamp bulb. The mercury atoms in the tube absorb some of the energy supplied by passing electrons and become excited.

Excited atoms can lose this energy in a number of ways to relax back into a lower energy state. One way to get rid of the excess energy is to emit it as light.

Atoms emit light of characteristic colors. Since the wavelength of light determines its color, there is a characteristic set of wavelengths of radiation that each atom emits. For example, mercury atoms will emit the following specific wavelengths of visible light:

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>435.8</td>
<td>blue</td>
</tr>
<tr>
<td>546.1</td>
<td>green</td>
</tr>
<tr>
<td>577.0</td>
<td>yellow</td>
</tr>
<tr>
<td>579.0</td>
<td>yellow</td>
</tr>
</tbody>
</table>

The light emitted by a fluorescent light bulb containing mercury vapor is a mixture of all of these colors. If light from a mercury vapor lamp is separated into its component wavelengths, a line spectrum is obtained:

Light is separated in just this way when it passes through a prism or over a diffraction grating. Prisms and diffraction gratings bend light rays of different colors by different amounts. If light from excited atoms is passed through a prism it is separated into a line spectrum which can be photographed and analyzed. The spectroscope is a simple device that disperses light passing through an entrance slit into a line.

Quantum mechanics offers an explanation for the existence of line spectra. According to the quantum theory, an atom is only permitted to take on certain discrete, fixed energies. No other
energies for the atom are possible. When an excited atom drops from a high energy state to a low energy state, the frequency (and wavelength) of light emitted is dictated by the energy difference between the two energy states:

\[ E = E_{\text{final}} - E_{\text{initial}} = h \cdot n = hc/\lambda \]

where \( h \) is Planck's constant \( (6.626 \times 10^{-34} \text{ Js}) \), \( n \) is the frequency of the emitted light, and \( \lambda \) is the wavelength of emitted light. Thus the lines observed in the line spectrum of an atom arise when the atom relaxes from a particular excited state to a particular lower energy state.

**Prelab Questions**

1. Compute the frequency of the yellow 577.0 and 579.0 nm mercury lines.
2. Compute the difference between mercury atom energy states that corresponds to each of these lines.
3. If both of these lines have the same lower energy state, use the energy level spacings calculated in the last question to sketch an energy level diagram for the mercury atom. Show how the two yellow lines arise as transitions between energy levels.