# Why Are the Colors in Some Rainbows Broken?

**Subject area/course**: Science, Chemistry

**Grade level/band**: 11–12

**STUDENT PROMPT SECTION**

1. **Task context**:

Everybody has seen rainbows, but where do the colors in a rainbow come from? If we want to see a pretty rainbow, do we have to wait for the perfect conditions after a rainstorm? The rainbows we see after a rainstorm have various colors seamlessly connected; is it possible to see a broken rainbow (with the colors disconnected)?

The various colors in a pretty rainbow come from visible light. Visible light is a small region of electromagnetic radiation. It contains light with a range of energies or a range of wavelengths (roughly between 400 nm and 700 nm). When the light of all the wavelengths mixes together, we see white light. After a rainstorm, the small water droplets in the air disperse the light from the sun and light is separated into different wavelengths; we therefore see a rainbow. It turns out that it is possible to manually produce a rainbow whenever you want. One way to do this is to pass white light through a prism or a diffraction grating. The light of various wavelengths can be separated and we see a rainbow – a spectrum of colored lights.

Light from various sources produce different kinds of spectra. White light from the sun contains light with wavelengths in the entire visible region; it therefore produces a *continuous spectrum* (a complete rainbow) when passing through a prism. Excited atoms also emit light. However, since the energy levels of an atom are quantized, the light emitted by excited atoms only contains light with certain wavelength values. Light from excited atoms therefore produce a *line spectrum* (a broken rainbow) when passing through a prism.

There are two parts of this task. In Part I, you will first research the light sources of two commonly used light bulbs, specifically an incandescent light bulb and a fluorescent light bulb. Based on your research, predict the type of spectrum incandescent light and fluorescent light will produce when passing through a prism or a diffraction grating. You will then use a diffraction grating slide to observe the emission spectra of an incandescent light bulb and a fluorescent light bulb. Sketch the spectra you observe; discuss and explain any similarities and differences between the two spectra.

In Part II of the task, you will research the light produced by excited hydrogen gas. You will determine the number of visible emission lines that excited hydrogen gas will produce and the color of each emission line. You will then use the Bohr model to calculate the energies of the visible hydrogen emission lines (the Balmer series), and use Planck’s equation to determine the corresponding wavelength of each emission line.



*nf* is the energy level in which an electron is found in the final state

*R* is the Rydberg constant (1.0974 107 m–1)

*h* is Planck's constant (6.626 10–34 J⋅s)

*c* is the speed of light (2.998 108 m/s).

*Rhc* = 2.179 10–18 J/atom

The electron transitions producing the four hydrogen emission lines in the Balmer series are:

a) n = 6 → n = 2

b) n = 5 → n = 2

c) n = 4 → n = 2

d) n = 3 → n = 2

*Note:* The energy, E, calculated using the Bohr model will be a negative value because energy is released in each of the above electron transitions.

To find the wavelength of each emission line from its energy, you will use Planck’s equation:

E = hc/λ

*Note*: Use the absolute value of energy determined from the Bohr model in this calculation.

Next you will use a diffraction grating slide to view the emission lines of a hydrogen gas discharge tube; record the color of each line and use the scale on the diffraction grating slide to determine the wavelength of each line. (*Note:* you should be able to observe at least three very bright hydrogen emission lines.) Compare these experimentally-determined wavelengths to those that are theoretically-calculated based on electron transitions between energy levels using the Bohr model. Based upon these wavelength comparisons, relate a particular electron transition (e.g., n = 3 ton = 2) to each colored emission line observed, evaluate the validity of the Bohr model when applying to hydrogen atoms, and discuss the limitations of the Bohr model.

1. **Final product**:

After researching the light sources of incandescent light, fluorescent light, and a hydrogen discharge tube, and the effect of various light sources on the emission spectra produced by incandescent light, fluorescent light, and excited hydrogen gas, write a 2-page paper that explains

1. any similarities and differences between the emission spectra of incandescent light

and fluorescent light, and

1. the various colored hydrogen emission lines using electron transitions described by the Bohr model.

Support your position with evidence from your experimental observations of the emission spectra of an incandescent light bulb, a fluorescent light bulb, and a hydrogen gas discharge tube using a diffraction grating slide and the Bohr model calculations of the Balmer series of hydrogen emission lines.

Your paper should:

* + Analyze and discuss experimental observations and generate scientific reports.
  + Generate a testable question, make a hypothesis, analyze data and support or refute your hypothesis in a two page, peer edited paper.
  + Synthesize and evaluate your experimental evidence to make recommendations about the Balmer Series and the Bohr Model.
  + Provide a concluding statement or section that follows from and supports the information or explanation provided.
  + Include your calculations, using the Bohr model and Planck’s equation, of the wavelengths of the hydrogen emission lines in the Balmer series.
  + Discuss limitations of the supporting studies, specifically the limitations of the Bohr Model.
  + Use discipline-specific vocabulary.
  + Be peer edited and revised according the suggestions.

1. **Materials/resources:**

You may use the Internet to research the concepts from this task.

Materials and equipment required for the experiment and data analysis:

* An incandescent light bulb
* A fluorescent light bulb or tube
* Diffraction grating slide
* Spectrum tube power supply
* Spectrum tube-hydrogen gas
* Scientific or graphing calculator

1. **Time requirements:**

This task will take approximately 7 hours to complete. Your teacher will provide additional details regarding deadlines and due dates.