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

**Grade level/band**: 10-12

**Task source**: Educational Policy Improvement Center (EPIC)

# Why Are the Colors in Some Rainbows Broken?

**TEACHER'S GUIDE**

1. **Task overview**:

In this task, students observe, compare, and explain the continuous spectrum produced by incandescent lights and the line spectrum produced by fluorescent lights. They also use a simple diffraction grating slide to record the wavelengths of the hydrogen emission lines in the visible region of the electromagnetic spectrum and compare these experimentally determined wavelengths to those that are theoretically calculated based on electron transitions between energy levels using the Bohr model. Based upon the wavelength comparisons, students evaluate the validity of the Bohr model when applying it to hydrogen atoms and discuss the limitations of the Bohr model.

This task will help students recognize the differences in the light sources of common light bulbs, understand the quantized energy levels in the electron structure of an atom, and explain the significance and limitations of the Bohr model.

1. **Aligned standards:**
2. **Common Core State Standards**

[CCSS.ELA-Literacy.RST.11-12.1](http://www.corestandards.org/ELA-Literacy/RST/11-12/1/) Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

[CCSS.ELA-Literacy.RST.11-12.2](http://www.corestandards.org/ELA-Literacy/RST/11-12/2/) Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.

[CCSS.ELA-Literacy.RST.11‐12.3](http://www.corestandards.org/ELA-Literacy/RST/11-12/3/) Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.

[CCSS.ELA-Literacy.RST.11-12.7](http://www.corestandards.org/ELA-Literacy/RST/11-12/7/) Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem.

[CCSS.ELA-Literacy.RST.11-12.8](http://www.corestandards.org/ELA-Literacy/RST/11-12/8/) Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

[CCSS.ELA-Literacy.RST.11-12.9](http://www.corestandards.org/ELA-Literacy/RST/11-12/9/) Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

1. **Critical abilities**

Research: Conduct sustained research projects to answer a question (including a self-generated question) or solve a problem, narrow or broaden the inquiry when appropriate, and demonstrate understanding of the subject under investigation. Gather relevant information from multiple authoritative print and digital sources, use advanced searches effectively, and assess the strengths and limitations of each source in terms of the specific task, purpose, and audience.

Analysis of Information: Integrate and synthesize multiple sources of information (e.g., texts, experiments, simulations) presented in diverse formats and media (e.g., visually, quantitatively, orally) in order to address a question, make informed decisions, understand a process, phenomenon, or concept, and solve problems while evaluating the credibility and accuracy of each source and noting any discrepancies among the data.

Experimentation and Evaluation**:** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. Evaluate hypotheses, data, analysis, and conclusions, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

Interpersonal Interaction and Collaboration: Develop a range of interpersonal skills, including the ability to work with others, to participate effectively in a range of conversations and collaborations.

Use of Technology:Present information, findings, and supporting evidence, making strategic use of digital media and visual displays to enhance understanding. Use technology, including the Internet, to research, produce, publish, and update individual or shared products in response to ongoing feedback, including new arguments or information.

Communication in Many Forms: Use oral and written communication skills to learn, evaluate, and express ideas for a range of tasks, purposes, and audiences. Develop and strengthen writing as needed by planning, revising, editing, and rewriting while considering the audience.

Modeling, Design, and Problem Solving:Use quantitative reasoning to solve problems arising in everyday life, society, and the workplace, e.g., to plan a school event or analyze a problem in the community, to solve a design problem or to examine relationships among quantities of interest. Plan solution pathways, monitoring and evaluating progress and changing course if necessary, and find relevant external resources, such as experimental and modeling tools, to solve problems. Interpret and evaluate results in the context of the situation and improve the model or design as needed.

1. **Next Generation Science Standards**

HS-ESS3-4. Design or refine a solution to a complex real-world problem, based on scientific knowledge, student- generated sources of evidence, prioritized criteria, and tradeoff considerations.

HS-PS2-6. Communicate scientific and technical information (e.g. about the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically).

1. **Time/schedule requirements:**

Students will need about 7 hours to complete this task. They will need 3 hours to research the various sources of light and their effect on the emission spectra of lights and calculate the wavelengths of the hydrogen emission lines in the Balmer series using the Bohr model and Planck’s equation. Students will need about 2 hours to conduct the experiments and analyze experimental results, and 2 hours to generate the task report paper.

The 7 hours of time can be all in‐class or can be split as 3 hours of out-of-class research and calculations, 2 hours of in-class experimentation and analysis/discussion, and 2 hours of out-of-class time to write the task report paper.

1. **Materials/resources:**

* Any college-level general chemistry textbook for knowledge of electromagnetic radiation, atomic emission line spectra, and the Bohr model
* A useful web site that students could consult while conducting research: <http://www.chemguide.co.uk/atoms/properties/hspectrum.html>
* Materials and equipment needed for the experiment:
* An incandescent light bulb
* A fluorescent light bulb or tube
* Diffraction grating slides - linear 1000 line/mm
* Spectrum tube power supply
* Spectrum tube - hydrogen gas

1. **Prior knowledge:**

Students should be able to:

* Describe electromagnetic radiation or radiant energy
* Explain atomic emission line spectra
* Use the Bohr model to calculate the energy involved in an electron transition between two energy levels of a hydrogen atom
* Use Planck’s equation to relate the energy and wavelength of a light
* Analyze and discuss experimental observations and generate scientific reports

1. **Connection to curriculum:**

None listed.

1. **Teacher instructions:**

Students can either work individually or in small groups of 2 to 3 to accomplish this task.

Preparation:

* + Students research the light sources of various commonly used light bulbs, specifically incandescent light bulbs and fluorescent light bulbs, and predict the type of spectrum incandescent light and fluorescent light will produce when passing through a prism or a diffraction grating based on their research.
  + Students research the light produced by excited hydrogen gas, determine the number of visible emission lines excited hydrogen gas will produce and the color of each emission line.
  + Students 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.

Experimentation:

* + Students use a diffraction grating slide to observe the emission spectra of an incandescent light bulb and a fluorescent light bulb and sketch the spectra they observe.
  + Students 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.

Analysis and Discussion:

* + Students compare the emission spectra of an incandescent light bulb and a fluorescent light bulb, describe any similarities and differences between the two spectra, and discuss and explain these similarities and differences using information they find regarding the light sources of these two different light bulbs from their research.
  + Students compare the experimentally determined wavelengths of hydrogen emission lines to those that are theoretically calculated based on electron transitions between energy levels using the Bohr model. Based on these wavelength comparisons, students relate a particular electron transition 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.

(*Notes for the teacher*: Red line corresponds to n = 3 →n = 2 electron transition; green line corresponds to n = 4 →n = 2 electron transition; blue line corresponds to n = 5 →n = 2 electron transition. The emission line produced by n = 6 →n = 2 electron transition has a wavelength very close to the purple edge of the visible spectrum, most times students are not able to view this line.)

Task Report:

* + Students write a 2-page paper that explains any similarities and differences in the emission spectra of incandescent light and fluorescent light, and relate the various colored hydrogen emission lines to electron transitions described by the Bohr model.
  + Students support their arguments with evidence from the 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/Planck’s equation calculations of the hydrogen emission lines in the Balmer series.

1. **Student support:**

The following suggestions are examples of scaffolding that can be used to meet the diverse student needs within the classroom.

* + Provide class time for research on students’ topics
  + Provide students with the rubric to be used to score their final product
  + Provide definitions of new vocabulary words ahead of time
  + For the final product, all learners will benefit from peer assistance while brainstorming their topics, as well as a peer or teacher reviews of their papers before final submission
  + Some students will have good research skills, but some will need guidance in the determination of appropriate sources and where to look for them. It is important to spend class time in review of what constitutes an appropriate source in advance of students’ independent work time.

1. **Extensions or variations:**
   * Students could present the results of their research to the class via an oral or multimedia presentation.
   * If there is a particularly interesting and/or controversial topic, a debate could be organized where students choose sides on the topic and defend their views.
2. **Scoring:**

Student work can be scored using the College and Career Ready (CCR) Task Bank Scoring Rubric.