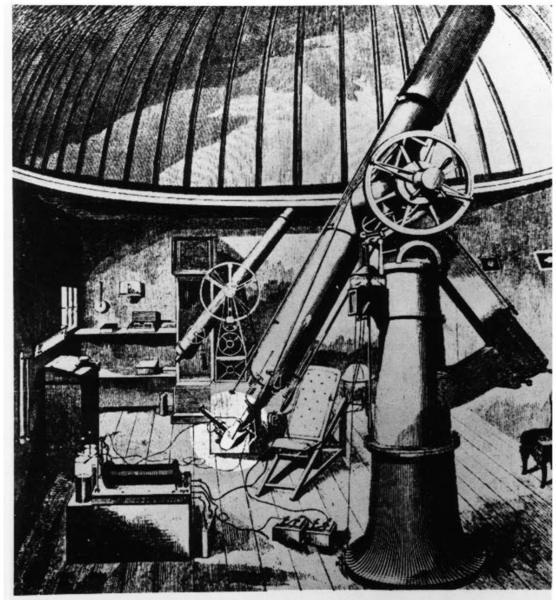
Lesson Plan
Spectra and Margaret Huggins



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Grade Level(s): 9-12	**Subject(s): Physics, Chemistry, Astronomy, History**
In-Class Time: 75 Minutes	**Prep Time: 15-20 minutes**

Materials

- **Either** printed handouts
  - Margaret Huggins Fact Sheet (found in the Supplemental Materials)
  - Element Identification Activity (found as a handout in the Supplemental Materials)
  - Slides from the PowerPoint whose content would serve well in a handout
- **Or** "Spectra and Margaret Huggins" PowerPoint and projection capabilities
- **Optional:**
  - Diffraction glasses
  - Gas discharge/spectrum tubes
  - Gas discharge/spectrum tube power source
  - Society of Physics Students 2014-15 SOCK supplemental activity, "Excited gases"

Objective

Students will expand on their knowledge of atomic absorption and emission by learning what spectra are and how we use them to study space. They will also learn about astronomer Margaret Huggins and her contributions to the field of spectroscopy.

Introduction

At the start of this lesson, students should have already learned that "atoms of each element emit and absorb characteristic frequencies of light, and nuclear transitions have distinctive gamma ray wavelengths. These characteristics allow identification of the presence of an element, even in microscopic quantities" (from Next Generation Science Standard PS4.B: Electromagnetic Radiation). Here, students will observe spectra produced in a laboratory setting. These spectra can be observed in the classroom as they are physically reproduced using gas discharge tubes (also called spectrum tubes), the appropriate power supply and diffraction glasses. Alternatively, students may observe images of this set up and the resulting spectra. The emission lines that they observe will be unique to the element creating the emission. The separated light that they observe through diffraction glasses is referred to as a spectrum (plural spectra).

Scientists can record and measure spectra in order to learn about the source of the emitted light. Astronomers have been using spectra to learn about the chemical makeup of objects in space (e.g. stars, nebulae, galaxies) since the nineteenth century. They do this by comparing the emission/absorption lines of elements and molecules as observed on Earth to the emission/absorption lines of observed objects in space. If the lines match up, then that element or molecule is present in the object being observed. Nineteenth century astronomer Margaret Huggins advanced this type of astronomical analysis, known as spectroscopy. She and her husband, William Huggins, were early spectroscopists who used spectra to study the chemical makeup of the sun, stars and nebulae. Margaret Huggins had a background in photography which proved invaluable in their incorporation of photography into spectroscopy. They were the first astronomers to integrate dry plate photography into their observations.

Modern-day spectra are analyzed in a different form than they were in the nineteenth century. Back then, astronomers looked at the emission/absorption lines they observed in a spectrum taken from an object. Today, astronomers often plot their spectra on graphs of wavelength versus either flux or intensity and analyze the features of these plots. Modern spectral analysis reveals other properties of astronomical objects, such as their movements and their distances from Earth. This is done by measuring the redshift of an observed spectrum. An observed redshift can be categorized as either a Doppler redshift or a cosmological redshift. The Doppler Effect is the change in wavelength of light or sound caused by the movement of the source toward or away from the observer. Something moving away from the observer will look redshifted, meaning the wavelengths of its light appear longer. Something moving toward the observer will look blue shifted, meaning the wavelengths of its light appear shorter. Astronomers can measure this shift and figure out how quickly an object is moving toward or away from the Earth. The cosmological redshift, however, is a different phenomenon that looks the same in observations as the Doppler Effect, but is caused by a different sort of physical movement. The cosmological redshift is caused by the expansion of the universe rather than by the motions of galaxies. Light from distant galaxies is redshifted because space has expanded during the light's journey (causing the wavelength of the light to increase, making it appear redder). Cosmological redshift is experienced the same way in all directions and is dependent only on the distance between the observer and the object, so measuring this effect allows astronomers to calculate how far away an object is from Earth.

Instructions

Engage: 10 minutes

In this section of the lesson, the students will recall what they have already learned about the excitation of atoms. Students will look at the emission spectra of different elements. They will learn about the different tools that allow them to view these spectra.	
What is the teacher doing? Review what the students have learned about atomic emission and absorption. Have the students explain what is being represented on the Atomic Absorption/Emission slide of the PowerPoint (see Supplemental Materials). Address any questions or points of misunderstanding that may arise.	**What are the students doing?** Look at and explain the Atomic Absorption/Emission slide of the PowerPoint. Ask the teacher any remaining questions/clarify points of confusion.
If spectrum tubes, a power source and diffraction glasses <u>are</u> available: Set up the spectrum tubes and power source. Give the students diffraction glasses. Turn on the power source and let the students observe the emission spectrum. Show them multiple gases, if possible. Lead them through the Discussion Questions found below. For further instruction on how to lead this activity, please see the Society of Physics Students 2014-15 SOCK supplemental activity, "Excited gases". **If spectrum tubes, a power source and diffraction glasses are <u>not</u> available:** Project the spectrum viewing slide. Lead them through the Discussion Questions, found at the end of this lesson plan.	**If spectrum tubes, a power source and diffraction glasses <u>are</u> available:** Observe the emission spectra of various gases. Participate in the discussion about what they are seeing. (Handout/PowerPoint slide can be used to explain what's happening in the experimental setup). **If spectrum tubes, a power source and diffraction glasses are <u>not</u> available:** View the handout/slide describe how spectra are produced and how we can view them for study. Answer the Discussion Questions.

Explore: 20 minutes

Students will learn how spectra help us learn about space. They will also learn about astronomer Margaret Huggins and her work in spectral photography.	
What is the teacher doing? Ask the students how they think astronomers could learn about the chemical composition of space by looking at spectra.	**What are the students doing?** Answer that astronomers can study spectra from objects in space (e.g. stars, galaxies, nebulae) and compare those spectra to the spectra observed on Earth caused by different elements. By matching up the spectral lines, astronomers can determine the chemical composition of objects in space.
Either hand out or project the Element Identification activity.	Complete the Element Identification activity.

Either handout or project the fact sheet about Margaret Huggins.	Read about Margaret Huggins.

Explain: 25 minutes

Students will play the role of a 19th century astronomer and write a letter/article convincing the scientific community of what they found in the Element Identification activity in the previous section of this lesson, imagining the argument Margaret Huggins had to convince the community that the nebula did not contain magnesium.	
What is the teacher doing? Prompt the students to write a letter to the 19th century astronomy community. Remember that Margaret Huggins was doing revolutionary work at the time and the greater astronomical community may not have known about spectroscopy or atomic emission. They should describe their process of spectroscopy and defend the chemical composition of the unknown object that they determined in the Element Identification activity.	**What are the students doing?** Write a letter from the perspective of a 19th century astronomer detailing the process and science behind spectroscopy and try to convince their reader that the unknown object from the Element Identification activity has the chemical makeup that they determined.
Have the students switch letters and assess the other student's argument, commenting on the clarity of their scientific explanation and whether or not they, as a representative of the 19th century astronomy community, would be convinced of the other student's claims.	Read another student's response and assess the clarity of their scientific explanation and whether or not they believe the writer's claims.

Elaborate: 20 minutes

Students will learn about modern spectra and how spectra can teach us about space, discussing the Doppler effect and redshift, and how studying redshifts can tell us about the movements and distances from Earth of objects in space.	
What is the teacher doing? Show the students an example of modern spectra and talk about the differences between how astronomers studied spectra in the 19th century and the way that astronomers study spectra now. (see the introduction and the final slides of the PowerPoint for more information)	**What are the students doing?** Learn how modern spectral analysis compares to 19th century spectral analysis.
Teach the students about redshift and how astronomers use their understanding of redshift to learn about objects in space.	Learn about two types of redshift and how understanding this effect allows astronomers to learn about the motion and position of objects in space.

Evaluate:

The "Element Identification" activity, along with the written portion of their Explain activity, may be collected for grading.

Required/Recommended Reading and Resources

Required:

- Margaret Huggins Fact Sheet (found in the Supplemental Materials)

To learn more about Margaret Huggins, her husband and their work in spectroscopy:

- Becker, Barbara. "Dispelling the Myth of the Able Assistant: Margaret and William Huggins at Work in the Tulse Hill Observatory," in *Creative Couples in the Sciences*, edited by Helena Pycior, Nancy Slack, and Pnina Abir-Am, 98-111. New Brunswick, NJ: Rutgers University Press, 1996.
- Becker, B. J. (2011). *Unravelling starlight: William and Margaret Huggins and the rise of the new astronomy*. Cambridge: Cambridge University Press.

Discussion Questions

1. **What do you see?**

Answer: Colors, bright lines of color near the spectral tube, rainbows by the regular lights.

2. **What do you think the diffraction glasses are doing to the light?**

Answer: Breaking up the light, splitting the light up in to different colors.

3. **What do you think is causing the bright lines by the spectral tube?**

Answer: The atomic emission from the gas inside of the tube.

4. **Do you think that those bright lines would change if there was a different gas inside of the tube?**

Answer: Yes. Different gases (different elements) emit different wavelengths (colors) of light when they're excited.

Further Reading and Additional Resources

<u>Related AIP Teacher's Guides on Women and Minorities in the Physical Sciences:</u>

- Dr. Elmer Imes and Spectroscopy – goes into depth about atomic emission/absorption, the refraction of light through a prism and what we can learn from spectra.

Extensions

N/A

Common Core Standards

For more information on Common Core Standards, visit http://www.corestandards.org/.

Science & Technical Subjects	
CCSS.ELA-LITERACY.RST.9-10.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

CCSS.ELA-LITERACY.RST.9-10.2	Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text.
CCSS.ELA-LITERACY.RST.9-10.6	Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, defining the question the author seeks to address.
CCSS.ELA-LITERACY.RST.9-10.8	Assess the extent to which the reasoning and evidence in a text support the author's claim or a recommendation for solving a scientific or technical problem.
CCSS.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	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.11-12.6	Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text, identifying important issues that remain unresolved.
CCSS.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.
Writing	
CCSS.ELA-LITERACY.WHST.9-10.1	Write arguments focused on *discipline-specific content.*
CCSS.ELA-LITERACY.WHST.11-12.1	Write arguments focused on *discipline-specific content*.

Next Generation Science Standards

For more information on the Next Generation Science Standards, visit http://www.nextgenscience.org/.

Dimension One: Practices	1. Asking questions and defining problems 3. Planning and carrying out investigations 7. Engaging in argument from evidence 8. Obtaining, evaluating, and communicating information
Dimension Two: Crosscutting Concepts	1. Cause and effect 5. Energy and matter
Dimension Three: Disciplinary Core Ideas	Core Idea ESS1.A: The universe and its stars Core Idea PS4.B: Electromagnetic radiation