Expo Station

Rainbow Spectroscope

Make a simple spectroscope so that participants can view the emission spectra of three different gases. Based on the color of the tube when placed in a power supply and visible spectral lines when viewed through the spectroscope, participants will attempt to identify the gas in each tube. Cards showing the spectral lines for each element, along with the distinct glow of the tube, will pair with observations to provide helpful hints.

Ages
9-14

Activity Time
Preparation: 20 minutes
Activity: 5-8 minutes

Group Size
Number of participants:
Up to 10 participants per hour at each station

Ratio of facilitators to participants:
1 facilitator can manage up to 3 participants each iteration

Concepts to Explore

- Each atom absorbs and reflects its own unique pattern of colors called spectra.
- Scientists know that our sun is made mostly of hydrogen and helium based on its emission spectra.

Safety Requirements & Other Considerations

- Safety glasses are appropriate for this activity.
- Place all cords on the facilitators side of the table. Then use gaffer's tape to secure them to the floor.
- The spectra tubes are made of glass and are very fragile, keep them each in their own power supply for the duration of the event. Only facilitators may handle them.
- Return any broken tubes to their cardboard boxes and label them "broken." Return them to the bin with the activity supplies.
- If a spectra tube becomes unusable, place it in its cardboard box and write "unusable" before returning it to the bin with the activity supplies.

Question to Investigate
Which gas is in each of three spectra tubes?

Materials Required
Per station

- Simple spectroscope made of
    - cardboard tube, 1.75 inches in diameter by 8 inches
    - aluminum foil, cut into 3-inch squares or circles
    - diffraction grating, either circle or square
    - masking tape
    - glue suitable for paper crafts, optional
- Print-outs of spectral lines of hydrogen, helium, and argon

Per table

- 3 power supply boxes
- 1 spectra tube: hydrogen
- 1 spectra tube, helium
- 1 spectra tube, argon
- 1 broken glass kit
- 2 permanent markers to label broken or damaged spectra tubes
- 1 power strip
- 1 extension cord
- 1 roll of gaffer's tape
- 1 pair of scissors

Preparation Prior to Activity

On-Site

- Carefully place one spectra tube in each power supply box.
- Plug the three boxes into the power strip. Use the extension cord to connect the power strip to the wall outlet. Turn the power supply boxes on to check them and then turn them off until participants arrive.
- Use gaffer's tape to neatly secure the cords to the table and floor. Unlike duct tape or packaging tape, gaffer's tape will not leave residue on carpets or floors.
- Place 3 sets of cards on each table so that each facilitator has his/her own set.
- Carefully insert one diffraction grating into one end of each cardboard tube. It should fit snugly with no need for glue.
- Fold three 3-inch circles of aluminum foil in half.

- Fold one of them again and use scissors to snip off the point. Open the circle completely and place it over the open end of your cardboard tube so that the hole is near the center. Tape the foil securely around the side of the tube with masking tape.
- Arrange the two semi-circles so that their diameters are very close to one another, leaving just enough separation to form a narrow slit. Secure these pieces in place with a rubber band.
- Adjust the spectroscope while looking at a light source. Turn the slit slightly until the rainbow stripes are as long as you can make them. Then use masking tape to secure the foil pieces so that the narrow opening well-positioned.

Instructions & Talking Points

Facilitate the activity		
Step	**Instructions**	**Talking Points**

Invite participants compare the color they see in each of the tubes in their power supply.	• Just looking at the tubes, what colors do you see?
	• Explain that each tube contains a different element and each element glows a distinct color.
		• Which tube appears more:
		  ○ Yellow?
		  ○ Blue?
		  ○ Pink?

Introduce the chart showing the visible spectra of the elements	Tell participants: • Elements are the basic ingredients that make up everything on Earth. This chart shows 99 of the 118 that we know about. • Each element has its own characteristic patterns of stripes of bright color against a black or dim background. Some elements have many bright lines while others have fewer. • These patterns are so consistent that scientists can use these patterns to identify	• Can you name an element? • What are the colors of a rainbow? • What does a rainbow and the chart of the visual spectra of the elements have in common? *The colors of a rainbow are the same as in the chart of the visible spectra of the elements.*

	which elements are in a sample, what the atmosphere of an exoplanet in another galaxy is made of, and the elements and relative amounts that make up our sun. • Let's see if you can identify three elements using a cardboard tube with foil and a small piece of plastic called a diffraction grating!	
Invite all participants to look through a spectroscope	Direct participants to: • Hold the spectroscope so that the colorful circle is near your eye and the foil end points to the light source. • Look at the lights on the ceiling as well as the three elements on the table. (Caution participants from looking directly at bright lights such as the sun.) Tell participants: • You will get a diffraction grating to take home with you so that you can look at lights with different kinds of light bulbs at home and in your neighborhood. This small gift is in the bag of items you will receive before you leave this room. • You can use the diffraction grating	• Do you see little lines with stripes of color when you look at each spectrum tube? • What similarities and differences do you notice?

	alone or make your own spectroscope with the instructions provided in the bag.	
Encourage participants to identify which of three printed emission spectra matches their observations.	For younger students, and those who are ready to leave, place the printed emission spectra near its tube-and-power-supply and flip the cards over to reveal which element is inside each tube. For participants who are up for a challenge direct them to: • Compare their observations through the spectroscope each of the three printed emission spectra shown on the table. • Either use questions such as those in the column on the right to guide them as they recognize the emission spectra for each of the three elements. • Or have participants work more independently. • Either way be sure to reveal the name of each element within the tube in Power supply 1, 2, & 3.	• Which tube contains an element that has a lot of yellow in its spectra? *You will see bright yellow stripe, a green stripe. The other colors will appear dim in comparison. This is the spectra for helium!* • Which tube contains the brightest stripes of green, red and blue? *Argon* • Which tube contains an element with blue and red being the brightest in its spectra? *Hydrogen*

Clean Up

- Turn off the three power supplies before unplugging the cords. Remove the gaffer's tape and place it in the trash. Return the cords to the bins.

- Carefully remove the spectra tube from each power supply and place it in its labeled box. Be sure to indicate whether it is damaged or no longer works well.
- Place each power supply in its box. Notice the number on the power supply itself and the number on the box. Then match them up.
- You may keep the remaining spectra tubes if you can use them in your outreach. Be sure that all volunteers have a chance to take one before taking multiples.
- Place everything else neatly inside the bin. Use paper or plastic filling to prevent items from shifting during transport back to ACS.

Explore the Chemistry

Sunlight reaches the earth as white light, which is made up of all the colors of a rainbow—red, orange, yellow, green, blue, indigo, and violet. A rainbow is a spectrum of visible light.

Visible light is made up of a range of wavelengths that our eyes and brain interpret as colors. To separate white light into these colors, the light needs to pass through a material which "bends" it. This bending of the light is called refraction. When you see a rainbow, the light from the sun passes through water drops in the air, which bends the light and splits it into its familiar different colors.

Chemists and physicists use a scientific tool, called a spectroscope to observe how light passes through different elements as electrons transition from a higher energy state to a lower one. The light might be continuous, like the light from the sun, or absorbed and emitted from the element. Light that is absorbed is observed as black lines along a range of rainbow-like colors. Light that is emitted is observed as lines of color in these same location and pattern along the range of visible light. These spectral lines are distinct for each element and this is why they are often compared to a fingerprint or barcode.

Spectroscopy is the study of how substances absorb and emit light. Early spectroscopy helped chemists Bunsen and Kirchhoff discover new elements. Chemical spectroscopy is still used today to identify which elements and compounds make up an unknown sample. Spectroscopy taught us that our sun is mostly made of hydrogen, followed by helium, and then trace amounts of about 65 other elements.

In this activity, we use a power supply box and spectra tubes each containing a different element—hydrogen, helium, and argon. The box runs electricity through the tube turning the gas to plasma and causing it to emit a color unique to each element. When we look at each spectra tube in the early part of the activity, we recognize that hydrogen has a pink-purple glow, helium has a yellow glow, and argon has a deep blue purple glow.

Looking through a simple spectroscope made of a cardboard tube, aluminum foil, and a small piece of plastic etched with 13,500 lines, can reveal differences when pointed toward each of the three different elements featured in this activity. It will be difficult to identify which patterns most closely match spectral lines. However, participants will recognize distinct differences.

It is important to note that the focus on colors in the emission spectra may imply that spectroscopy is only associated with visible light. This is not true. Instead distinct wavelengths are absorbed and emitted along the range of the full electromagnetic spectrum.

References

- Sherri C. Rukes is a member of the Committee on Community Activities and content contributor for the National Chemistry Week 2024 Theme Team, Photography & Imaging: Picture Perfect Chemistry. Ms. Rukes is an Honors and AP Chemistry Teacher at Libertyville High School in Illinois.

- *Afterschool Universe* program Leader's Manual

- *Spectroscopy, Explained* by NASA Goddard https://www.youtube.com/watch?v=_1mpHBAXh1c

- *Spectroscopy Transformed Astronomy, Chemistry & Physics* by Kathy Loves Physics & History. https://www.youtube.com/watch?v=TFP55200MPY