

LESSON GUIDE WITH TEACHER'S NOTES

Engage

1. Look at the pictures to the right and identify the “neon color(s).” Why is the word “neon” used to describe color?



A real "neon color" is the color made by gas tubes filled with neon and excited by electricity. Related fluorescent colors are not truly "neon" colors if other atoms (or pigments) are the source of those colors.

2. A planet's atmosphere is being analyzed to determine whether it could support intelligent life. From most to least important for supporting life, rank the following gases (nitrogen, oxygen, carbon dioxide, neon, helium, hydrogen). Justify your ranking.

Oxygen is obviously important for life, but carbon dioxide (at moderate amounts) is important on Earth for maintaining appropriate temperatures. Students might also know that noble gases tend to be unreactive and have little or no effect on life. Be open to other suggestions from students about dangerous and life-sustaining gases.

3. Describe or draw the spectra made by observing white and neon light with spectrometers.

Depending on your students' background, you might need to discuss rainbows as an everyday example of a spectrum. You could also connect to experience with prisms or diffraction gratings.

4. What are the safety concerns with electrifying gases in glass tubes?

Typical safety concerns are heated glass after electricity is run through the tubes, broken glass from the tubes being handled poorly, and a shock hazard from voltage applied by the spectrum tube carousel.

Explore

Before you begin, gather the necessary materials:

- A data table
- A spectroscope
- Colored pencils, pens, or markers to record your observations in color

Procedure:

1. Practice using the spectroscope by looking at sunlight (but don't look directly at the sun!) and/or an overhead light. The spectroscope will turn the light into a rainbow spectrum. Point the spectroscope slit at the light source and then, without moving the spectroscope, move your eye to the side to view the spectrum. Get help if you can't see the rainbows.
2. Look at the light emitted by gases in glass tubes. In the provided data table, record your observations under the following conditions:
 - a) Record the color of the gases when the electricity is off.
 - b) Describe the color you see *without* the spectroscope when electricity has been applied to the samples.
 - c) Use the spectroscope to observe lines of color emitted by the electrified gases. Use colored pens/pencils/markers to draw the spectrum and (if possible, with the spectroscope and as directed) record the wavelengths of the color lines in the spectra.
3. When you are finished observing the tubes, form peer groups to compare data. Help classmates who may have been rushed or missed a sample to complete their data set.

Explain

1. Were any of the gases particularly difficult or easy to observe with the spectroscope? Explain.

Answers will vary depending on the gas tubes you use. Often noble gases are brighter than non-noble gases.

2. Do the different types of gases emit similar colors or different colors? Which color(s) in the pictures from question 1 in the Engage section is/are true “neon” color(s)?

By switching the element/compound you can switch the color. Only one of the colors in the Engage will truly match the Neon color. Though if they count each line of color made in the spectrum for neon, students might say all those specific lines of color are neon colors.

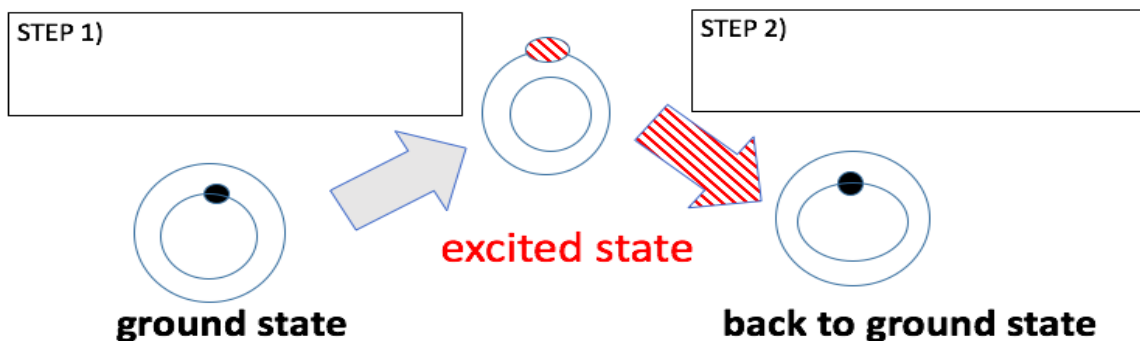
3. Does each electrified gas make one color or a mixture of colors? Justify your answer in words or by drawing a diagram.

Encourage students to realize that the color they see by eye is the result of mixing the individual lines of color revealed by the spectroscope.

4. Which gas sample emitted (showed) the fewest lines of color when observed by a spectroscope? Which gas sample emitted the most lines?

Answers will vary depending on the gases used. Hydrogen and helium are relatively simple spectra. Neon and air (oxygen) have more lines and are more complex.

5. The *Bohr diagram* below shows an electron (shaded circle) in different electron shells in a gas atom. Each thin circle represents an energy level where you might find the electron. What do you think is the difference between a “ground state” and an “excited state” electron?



6. Electricity plays a role as an external energy source during only “step 1” or “step 2.” Which step requires electricity (external energy)? Explain your guess.
7. Light is released only during “step 1” or “step 2.” Which step releases light energy from the atom to the surrounding environment? Explain your guess.
8. Fill in the *two* boxes in the diagram above with a word or two to summarize the change connected by arrows. Later, we will introduce science words for these changes.
9. Why do different atoms emit different specific colors? Make an educated guess or research the topic.
10. Can atoms release non-visible electromagnetic radiation as well as visible light?

Extend

1. Using the data below, make a sketch to predict emission spectra for Venus, Earth, and Mars. Look up the emission spectra for any type of gas you did not get to observe during the lab.

Planet	Venus	Earth	Mars
Surface Pressure (relative to Earth)	90	1	0.007
Carbon Dioxide (CO ₂)	96.5%	0.03%	95%
Nitrogen (N ₂)	3.5 %	78%	2.7%
Oxygen (O ₂)	Trace	21%	0.13%
Argon (Ar)	0.07%	0.9%	1.5%

Expect students to ask about how to make a spectrum for a mixture. The gas that's present in higher amounts would contribute more to the spectrum and would produce brighter lines. The mixture also results in more lines than any single gas type could contribute alone. If you have a glass tube sample filled with "air" in your collection, you can show that complex spectrum to your students to reinforce this concept.

2. Which components in each atmosphere make intelligent life more or less likely on these planets? Design an experiment to use emission spectra of atmospheres to search for intelligent life on other planets.

The answer can be quite complicated and invites an open-ended discussion. Oxygen, for example, is needed at moderate levels to support Earth-like life. Too much and the atmosphere would combust. Too little and respiration, which is required for all multi-cellular life on Earth, can't happen. Of course, even defining what "intelligent life" means would be an interesting discussion. Many bacteria can survive in non-oxygenated locations on Earth. Most exobiologists walk the line between being open-minded about what would be necessary for life, while looking for Earth-like planets and atmospheres because we know that Earth-like conditions can produce life.

3. The Northern Lights (Aurora Borealis) are produced by excited gases. Which kinds of gases get excited? Where do the gases get excitation energy needed to make Northern Lights? Why is this phenomenon observed at the poles and not at the equator?

Northern Lights largely result from light emission by oxygen atoms, though less so by oxygen molecules, found at about 100 km above the Earth. Solar radiation is required to break the oxygen molecule double bond to make atoms. Nitrogen atoms can also contribute to the Aurora, but the molecules are more stable and harder to convert into atoms due to the triple bond. The collisions with charged particles from the solar wind not only break bonds in molecules but also provide the excitation energy for emission. The charged particles in solar wind get channeled to the poles (and not the equator) by interactions with the Earth's magnetic field. In the absence of a magnetic field, the solar wind would bombard the entire planet. Your students may have heard that the lack of a magnetic field on Mars makes its colonization more difficult because constant exposure to that radiation would be harmful. Find out more [Atmospheric Optics](#).

4. When sharing data, do you think it is better to describe line spectra qualitatively or quantitatively (numerically)? Justify your answer by proposing the best way to share data.

Many students will recognize that color descriptions vary from person to person and can be affected by color blindness and other factors. Depending on the context and class, some students may recognize that color can be quantified by wavelength and frequency, especially if that point is raised during the Explain phase in describing the Bohr diagrams in slides 9 and 10.

Excited hydrogen atoms emit four wavelengths of visible light (plus many colors of non-visible electromagnetic radiation). The energy these light photons possess is small, so many physicists use the electron-volt (eV; $1\text{eV} = 1.6 \times 10^{-19} \text{ J}$) energy unit to measure these energies. The equation for calculating the energy (in eV) for light at a given wavelength (nm) is:

$$\text{Energy} = 1240 \text{ eV} \cdot \text{nm} \div \text{wavelength}$$

5. Use the equation to calculate the energy for the colors in the table. Enter the data into the table.

Slide 14 shows the answer to the calculation and includes an example calculation. This equation could be new to your students. You may have to discuss the relatively small size of the eV versus a Joule. You could also opt to use the equation with Planck's constant (E

= $hc / \text{wavelength}$) to get the same result with more conversions. It is the same underlying physics. The equation has the advantage of being a shortcut mathematically, but it may hide some of the physics you have covered previously.

6. Based on your calculations, summarize the relationship between wavelength and energy in a single sentence.

The relationship expected to answer question 6 is that as wavelength increases the energy decreases (or vice versa, that as wavelength decreases, energy increases). You could go deeper and ask students to graph the inverse relationship, which could help some students see the relationship better.

Color of Hydrogen emission line	Wavelength (nm)	Energy (eV)
Red	656.2	
Blue-Green	486.1	
Blue-Violet	434.0	
Violet	410.1	

Evaluate

1. Now that you have collected your data, add a *title* to the data table. In science, titles are *descriptive* and *detailed* to summarize the key *result* indicated by the data. Share your title in a tweet.
2. Share the results of your assigned **Extend** question research in peer groups.
3. You have been asked to design a sign for the school that uses electrified gas tubes to produce the desired colors. Draw a diagram to show the design for your sign. Make sure to label the gas used for each part of the sign. Research to find gases that can make colors you haven't seen yet but want to include.

Image Sources

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