NAME:________________________H. Chemistry Period________

EMISSION SPECTRUM LAB

BACKGROUND:

When a sample of hydrogen gas receives a high energy spark, the hydrogen molecules absorb energy and some of the H-H bonds are broken. The resulting hydrogen atoms are **EXCITED**, that is, they contain **EXCESS ENERGY**, which they release by emitting light of various wavelengths to produce what is called the **EMISSION SPECTRUM** of the hydrogen atom.

A **CONTINUOUS SPECTRUM** results when white light is passed through a prism. This spectrum, like the rainbow, contains all the wavelengths of visible light.

In contrast, when the hydrogen emission spectrum *in the visible region* is passed through a prism, we see only a few lines of color, each of which corresponds to a **DISCRETE WAVELENGTH**. This is called a **LINE SPECTRUM.**

The Line Spectrum shows that only certain energies are possible: the electron energy levels are **QUANTIZED!!** If any energy level were possible, the emission spectrum would be continuous.

MATERIALS:

Spectrum tubes(Hydrogen, Helium, Argon, Krypton, Unknown)
Spectrum Tube Power Supply
Student grade spectrometer

PURPOSE:

The primary objective is to familiarize students with the emission spectrum of various gasses and to link observations of spectral lines with the concept of quantization of electron energy levels in atoms. Use of a spectroscope and reinforcement of lecture-based problem-solving skills are additional objectives.

TASKS:

1. Using a spectroscope, observe the emission spectrum for the five gasses and also observe sunlight, white light from an incandescent bulb, and light from an ceiling fluorescent bulb.
2. Diagram the spectrum for each observation.
3. Using the Data Table from the Flame Test Lab, ESTIMATE the wavelengths of the spectral lines(one of the lines from each of the ROYGBIV colors present is sufficient).
4. Using $\Delta E = hc/\lambda$ calculate the increment of energy(the quantum) that is emitted at the wavelength of ONE of the spectral lines for each sample. Answer in Joules.
5. Using $\lambda v = c$ calculate the RANGE of frequencies exhibited in the emission spectrum of each sample(i.e. calculate the frequency for the longest and shortest wavelength observed- answer in Hertz.

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Quantitative Spectroscope #10010

Light: An Historical Perspective

At some time or other, you may have noticed one or more rainbows projected onto a table or wall from the rim of a glass or jelly jar or crystal that was placed in the sun. Where did these colors come from? Why were they always in the same order with red on one side and blue on the other? Only a few hundred years ago, these simple observations were the source of great interest for many scientists. At a time when it was commonly believed that light was made up of tiny particles called corpuscles, Christian Huygens (1629-1695), who had been studying the behavior of water waves, made a conceptual leap and transformed the scientific community by using models that described the behavior of water waves to explain the reflection and refraction of light. Light was not necessarily a particle after all, it behaved like waves of water!

As years passed, other great scientists such as Augustin Fresnel (the Fresnel lens) and Thomas Young (1773-1829) contributed experimental evidence to support the wave theory of light. Young's experiments, particularly those dealing with the diffraction of light conclusively demonstrated that light must travel in waves.

This conceptual model of light worked rather well until it began to fray at the edges at the turn of the century when scientists tried to explain spectra made by burning chemical salts in a flame. You see, these spectra were a little different; they did not stretch continuously from red to blue as the spectra of ordinary daylight does, but rather, had several bright lines and many large dark spaces in between.

The tide would soon turn on the wave theory of light and it would again be viewed as a particle when, in 1921, A.H. Compton demonstrated that light possessed momentum, a very particle like quality.

Today, our current theory of light now embraces both its wave and particle aspects. Light is an electromagnetic wave, that travels in small particle like packets called photons. Each photon travels at the same speed: 3×10^8 m/sec, the speed of light. The energy of a photon is determined by its frequency (color). The higher the frequency, the more energy it contains. The higher the frequency, the bluer the light, the lower the frequency the redder the light. We are all familiar with ROY G. BIV. The letters stand for the colors in the rainbow with Red, Orange, Yellow, Green, Blue, Indigo, and Violet. These colors are listed in order of increasing energy (decreasing wavelength) and comprise our visible spectrum. But the electromagnetic spectrum doesn't stop there! It continues beyond the visible into higher energies with ultra violet, x-rays, and gamma rays. It also extends below red into lower energies with infra red, and radio waves.

Where does light come from?

Electromagnetic radiation (in our specific case, light) is created when an electron moves from a higher energy level (electron orbit) to a lower energy level. The photon of light that is emitted has an energy that corresponds *exactly* to the difference in energy between the two orbits.

Diffraction Gratings

The heart of the spectroscope is the diffraction grating. This is a thin film of plastic with thousands of very closely spaced lines etched in its surface, in our particular case, 5000 lines per ~~inch~~ cm. This grating uses a combination of diffraction to bend the light waves as they pass by the lines etched on its surface, and interference to constructively add colors at certain locations and destructively eliminate colors at other locations. What you end up with after a beam of light is passed through a diffraction grating is a separation of the colors (wavelengths) of which the incoming light beam was composed.

Using the Spectroscope

Hold the spectroscope so the small end with the square hole is toward you. The wider, curved end has a narrow slit (which lets light into the spectroscope) and a wide window with a numbered scale. While holding the spectroscope a few inches in front of your eye, look through the eyepiece of your spectroscope (the square hole in the small end of the spectroscope which holds the diffraction grating) and point the slit end at an incandescent light bulb. The numbered scale should be to the left of the slit as you look through the eyepiece. You should find that a continuous spectrum is located on the left side of the bright "white" slit. Be sure the slit is pointed directly at the light source for the best and brightest spectrum. Each number on the scale indicates the wavelength of light in angstroms when multiplied by 1000 (that is, a reading of 5 on the scale is equivalent to 5000 angstroms, 1 angstrom equals 1×10^{-10} meters). Most solids that are heated to glowing (like the filament of a light bulb) will produce a smooth distribution of colors called a continuous spectrum.

Types of Spectra

Continuous Spectra:
What we commonly refer to as a rainbow. Continuous spectra are usually produced by a luminous liquid or solid, such as the glowing filament of a lamp.

Emission Spectra:
or bright line spectra whose source is a glowing gas. This gas emits photons with very specific energies (frequencies, wavelengths) that are characteristic of the chemical element of which the gas is composed.

Absorption Spectra:
or dark line spectra which is generated by having a continuous spectra (white light) pass through a cooler gas located between the source of the continuous spectrum and the observer. The cooler gas absorbs those wavelengths that it would normally emit if it were the glowing source. The dark line spectra has the same spectral fingerprint that the cooler gas would if it were emitting a bright line spectra. You can think of the absorption spectra as the photographic negative of the bright line spectra.

Chemical Fingerprints

Because each element has a different atomic structure, the electrons that orbit the nucleus emit photons of light at frequencies that are very characteristic of that particular atom. One could say that the bright line *emission* or dark line *absorption* spectra is a chemical fingerprint for the particular element in question.

So, given a particular spectra, we should be able to identify each wavelength present and pair them up to match the "fingerprints" of known elements to determine which elements are present in the material producing the spectra! Just like detectives fingerprinting the crime scene to determine who the criminal was!

Try looking at a fluorescent light bulb with your spectroscope. Now, instead of a smooth continuous spectrum you see several bright lines. One is violet, one is cyan (light blue-green), one is green, one is yellow, one is orange, and a couple of red lines. This spectra is primarily produced by mercury vapor. Try looking at other types of lamps, such as neon, or sodium vapor lamps. How do these compare? Compare other light sources if you can, such as halogen lamps, gas lanterns, automobile head lamps, LED's etc. Can you tell which lamps use solid filaments by looking at their spectra?

Other bright line spectra can be produced by burning salts of various chemicals in a gas (Bunsen burner) flame. Some common elements are:

Copper	5300	Green
Sodium	5890	Yellow
Strontium	6060	Orange
Lithium	6708	Red

Note that sodium is very common and very bright and may be present in many flame spectra as a trace of contamination. These salts can be introduced into a flame by dipping a hot wire into the chemical salt then bringing the salt coated wire to the base of the Bunsen burner flame. The flame will begin to burn with a color characteristic of the salt used.

Some elements are contained in low pressure gas tubes called spectrum tubes that are similar to fluorescent lights. Higher resolution spectral lines for some of these elements are given below:

Hydrogen	6562, 4861, 4340
Mercury	4358, 5460, 5769,5790
Helium	4471, 4713, 4921, 5015, 5875, 6678
Sodium	5889, 5895

Note that in many cases closely spaced spectral lines may not be resolvable with this spectroscope and wavelength data is given for reference only.