

Name:

Class:

ACTIVITY 5
Applying Spectra and Energy Diagrams
to Learn About Stars

Goal

Now that we can use energy diagrams to describe the emission of light by gases we will apply this knowledge to see how scientists learn about the composition of stars.

The study of spectra in all its forms plays an important role in determining the chemical make-up of matter. Spectra can be considered as the fingerprints of matter. Every atom emits its own characteristic spectrum of light. The study of spectra has been an important tool for scientists to identify the chemical composition of substances isolated in chemical, biological, and astronomical research. For example, the study of spectra from starlight showed that the sun and some of the stars are made of hydrogen and helium. Helium was actually discovered in the analysis of solar spectra before it was discovered on earth. In this activity we will learn how scientists were able to discover helium on the sun even though they had not yet isolated it on earth.

Warning: Never look directly at the sun. To view the sun's spectrum place white paper in sunlight. Look at the light reflected from the paper.

The sun, and other stars, produce the light that we see by a process similar to the one used in incandescent lamps. Material near the surface of the star becomes very hot. Some of the energy is emitted as a light.

During the last century, scientists looked carefully at the spectrum of the sun. They saw something similar to the spectrum that you saw for the incandescent lamp. It was continuous but it had an important difference — dark lines appeared in the sun's continuous spectrum. An example of this type of spectra is represented in Figure 5-1. The gray area represents light coming through while the black lines show some of the places where no light was seen.

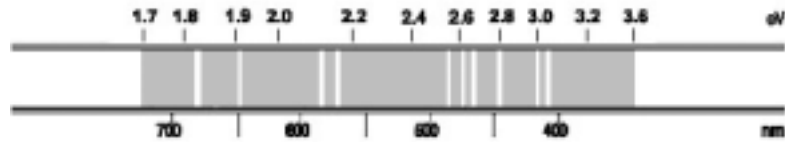


Figure 5-1: Some of the spectrum of a sample star.

While this spectrum is similar to previous ones we have studied, it also has some unique features. As we understand it we will learn that:

These dark lines can be used to identify elements as well as the bright lines in the emission spectra of gases can.

A process that is similar, but not identical to emission creates the dark regions in this spectrum.

Begin by comparing the dark lines in the solar spectrum with the lines of light from the gases shown in Figure 5-2.

Hydrogen:



Nitrogen:

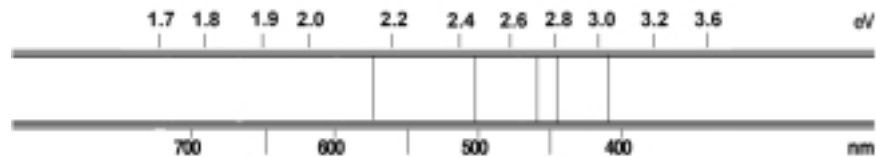


Figure 5-2: The light emission spectrum of hydrogen and nitrogen.

? What similarities do you see between the hydrogen and nitrogen spectra and the spectrum of the star?

- ? Do you think that you see evidence for the presence of hydrogen or nitrogen on the sun? Explain your answer.

We see a rather close match of the energies in the gas spectra with some of the energies of the dark lines of the star's spectrum. These observations are a hint that the process that produced the dark lines is related to the one that produced light in gases.

A sign which photographers sometimes have on darkroom doors reads "Keep the door closed so the dark will not escape." This joke plays on the idea that dark is the absence of light (or energy), so it cannot escape. We will use the same idea with the star's spectrum. The dark lines are energies that are missing from its spectrum. Each of these energies has been removed while other energies are present.

To understand the processes we need to think about energy in the light. In the previous activity we saw how light is produced by energy changes in atoms. Now think about what needs to happen for one energy of light to be removed from a beam containing all energies of visible light.

- ? Can you use the energy level diagram to describe how a photon of light can be removed from a beam of light?

A spectrum with dark lines in it is called an *absorption spectrum*. To help understand how absorption spectra occur we will use the *Spectroscopy Lab Suite* computer software.

In *Spectroscopy Lab Suite*, select *Absorption* under *Gas Lamps*.

Drag the figure of the hydrogen gas tube to the gas lamp socket. Figure 5-3 illustrates what should appear on the screen.

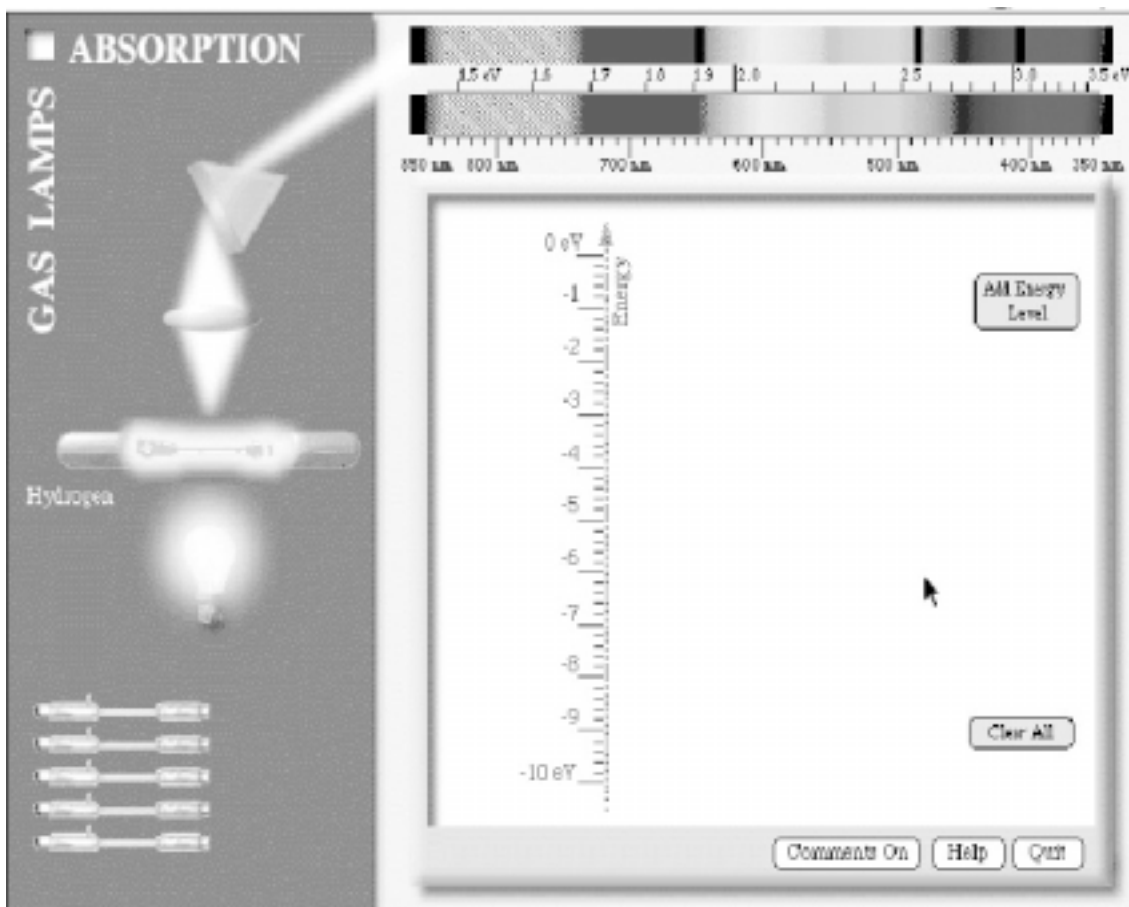


Figure 5-3: A screen from the *Spectroscopy Absorption* Computer Program

The dark (absorption) lines appear in the spectrum at the top of the screen.

To duplicate this spectrum, create and move energy levels and then put in the transitions.

An absorption transition, unlike an emission transition (which we constructed in the previous activity) is created by starting with a lower energy level (largest negative energy value) and ending with a higher energy level (smallest negative energy value). Notice that the arrows that represent the allowed transitions point upward. The arrows point upward to represent that the hydrogen gas absorbs these energies emitted by the light source. As a result, electrons acquire enough energy (equal to the difference of the allowed total energies) to move up to the higher allowed energies.

Sketch below the energy levels and transitions.

Once you have completed your diagram compare it to others in your class.

? How are the diagrams similar?

? How are they different?

Now, compare these energy levels and transitions to those of the emission spectrum for hydrogen that you created in Activity 4.

? How are the emission and absorption spectrum different?

Now, use energy considerations to describe how an atom absorbs a photon from a light source containing all visible energies.

? Suppose that we create a beam of light that has photons of energies only in region of 2.0 to 2.4 eV. That beam passes through a tube with hydrogen. Would you see dark lines in the resulting spectrum? Why or why not?

? Suppose this light (2.0 - 2.4 eV) passes through nitrogen. Would the resulting spectrum have dark lines? Why or why not? (The nitrogen spectrum is shown in Figure 5-2.)

Now that we can use energy levels to explain absorption spectra, we can return to the spectrum of our sample star. In a star a continuous spectrum is created as a result of an extremely hot environment. (More about this process will be discussed in a later activity.) A layer of relatively cool gases surrounds the star. Light emitted by the star passes through these gases. Atoms of the gases absorb photons and move from a lower energy state to a higher one. Then, photons of certain energies are no longer present in the light. Thus, we see dark lines — the absence of certain energies — in the spectrum of our star.

An important conclusion from this analysis is that absorption spectra can be used to identify elements in much the same way as emission spectra. 19th Century scientists used this identification process when they looked at the spectrum of the sun.

- ? Are both hydrogen and nitrogen present in the gases surrounding the star?

- ? Do you have any lines that are not accounted for by either hydrogen or nitrogen?

The 19th Century scientists went through this same process. The full solar spectrum had many more absorption lines than shown in Figure 5-1. The scientists were able to identify elements that could have absorbed photons associated with almost all of them. They even identified metals such as iron in the gases surrounding the sun. But, when they got done, they had some lines that they could not associate with any atom. These lines were the same ones that you had left over.

They knew that absorption of certain energies meant the presence of a certain type of atom. But, they had never seen either emission or absorption at these energies. So, an element not detected (in the 19th Century) on Earth must be in the gases around the Sun. They named the element helium after the Greek word helios, which means sun.