Name: Class:

SOLIDS & LIGHT

Visual Quantum Mechanics

ACTIVITY 6

Using Spectra to Search for an Earth-like Planet

Goal

Now that we can explain why gas lamps emit their characteristic spectra and how absorption spectra are related to emission, we will apply our knowledge in a science fiction type scenario. The purpose will be to identify the gases present on a mythical planet and determine whether conditions similar to earth exist there.

To continue the study of spectra imagine we are a group of scientists in a star ship. Our job is to look for planets that might be hospitable for humans. These plants are called Class M on Star Trek. Lots of planets exist around other stars so it is a big job. If we were to take the time needed to travel to each one – even at warp speed – and transport down, we might never finish the job. In fact, we would not want to transport down until we knew something about the atmosphere. So we need to investigate the gases in the atmosphere from afar.

Fortunately, we have the perfect tool for learning about the atmosphere without needing to get close to the planet. We can look at the light that passes through the atmosphere of the planet and see what energy photons are absorbed by it. The basic arrangement is shown in Figure 6-1.

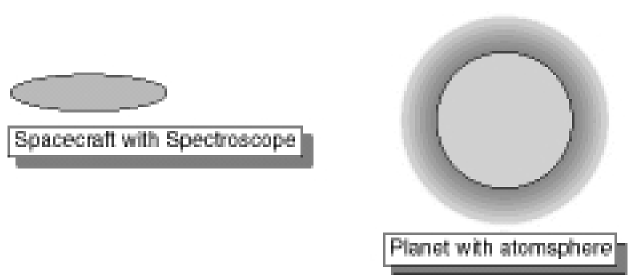


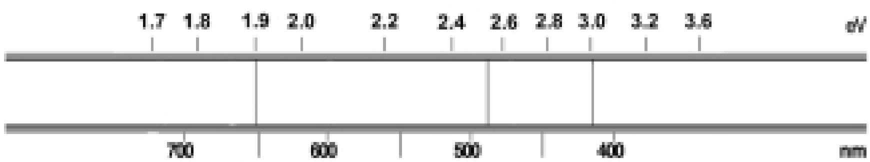
Figure 6-1: The arrangement of the starship, planet and a nearby star.

?	Our starship is equipped with very good spectroscopes. How would this arrangement allow us to investigate the elements in the atmosphere of the planet?

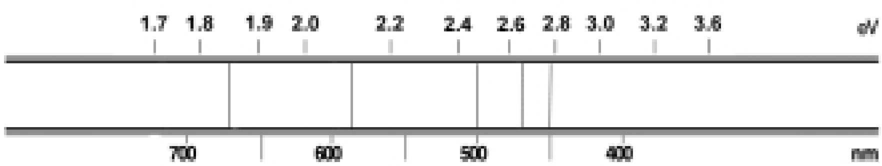
The astronomers on our starship team bring data showing the spectra absorbed by the planet's atmosphere, as observed through a telescope that has a spectroscope attached.

Our task is to use the recorded spectra and compare them with those of some commonly known terrestrial gases. Then we can determine what gases are present in the planet's atmosphere. The spectra of various known gases are illustrated in Figure 6-2.

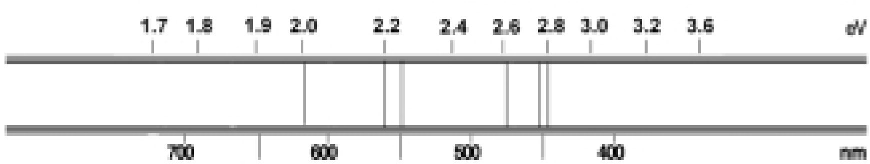
Hydrogen:



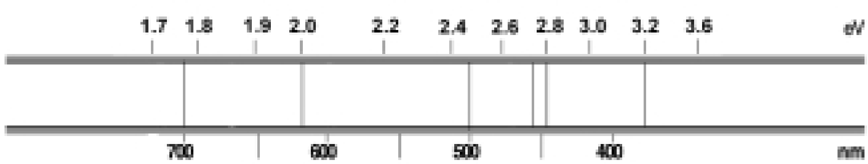
Helium:



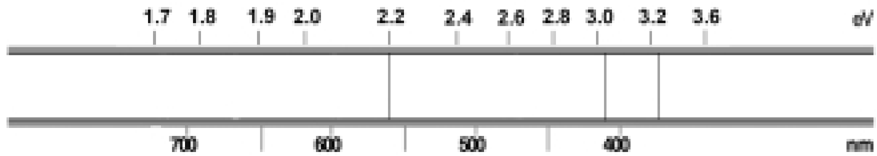
Carbon Dioxide:



Oxygen:



Ozone:



Nitrogen:

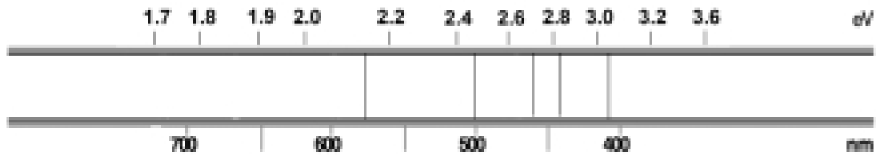


Figure 6-2: The Visible Spectra of Various Gases

? Looking at the list of gases found in Figure 6-2, what other gas(es) or substances, if any, would you add to this list if we were looking for conditions on a planet that could support life? Explain.

? Could any of the gases in our list on the previous page be omitted? Why or why not?

? Your teacher will give you a copy of the planet's spectrum. Compare the spectra of the planet's atmosphere with that of the other gases. Which of these gases are present in the planet's atmosphere? Support your conclusions.

? Are there any gas(es) other than the ones listed above present in the planet's atmosphere? Explain how you reached your conclusion. List the energies of any light that cannot be accounted for in gases listed on the previous page.

? Based on the information and your analysis describe and justify your conclusions about the similarity of this distant planet's atmosphere and earth's.

If other solar systems in the universe do contain Earthlike worlds they must have a planet at a distance from a star so that water can exist in liquid form. If the planet is too far away, it will only contain ice. Too close and all the water will be steam. Planets such as earth are very fortunate to be located where water can exist as gas, liquid and solid. Scientists use the term, "habitable zone" (defined as the planet's distance from its star in which water exists in liquid form rather than as a solid or a gas) in describing the probability of whether conditions could support life. The Galileo space probe launched by NASA passed over Jupiter and found that the atmosphere not only contained hydrogen, neon, helium, and noxious gases such as ammonia and methane but also had higher winds and less lightning and water than scientists had predicted.

The Galileo probe also found that Europa, one of Jupiter's moons, has an icy white surface and shows evidence of water and oxygen. Some scientists speculate that the surface could conceal oceans of water and perhaps some sort of living organisms. Europa was the focus of the science fiction movie, *2010*, in which the humans witnessed the birth of a cosmic event and were given a second chance to reconcile their national differences. NASA is making plans to possibly send three spacecraft to Europa to determine if it does have a water ocean.

Our neighboring planet, Mars, has also been the focus of science fiction movies like *War of the Worlds* and *Total Recall*. The thin atmosphere of Mars (less than 1% of Earth's) is made almost entirely of carbon dioxide with traces of nitrogen and argon. As a result of finding evidence of massive floods, scientists speculate that Mars, now a bone-dry salmon-colored surface, had water 1 to 4 billion years ago. If that is the case, scientists are optimistic in that one-cell microorganisms may still be surviving or at least fossil evidence may exist somewhere under the Martian landscape.

The *Mars Pathfinder* spacecraft[Note], was launched by NASA in December of 1996 and arrived on Mars in July of 1997. The project involved the landing of a spacecraft (called *Pathfinder*) that contains a miniature ground-roving vehicle (called *Sojourner*) with several instruments on board. As *Sojourner* moved across the surface of Mars at a speed of 2 feet per minute, the instruments on board identified and analyzed a wide variety of surface materials from the heavily cratered terrain to the ridged plains to channel deposits. The rover has a life span of about a month while the lander has a lifespan of a year. During these times, data will continue to be collected, analyzed, and reported back to Earth. Up to 10 missions are being planned by NASA by 2005, including a rock-gathering round trip.

One of the instruments is a circular spectrometer that is mounted near the front of *Sojourner* (See Figure 6-3.). By shooting electrically charged particles at objects on Mars it causes the atoms in the materials to emit energy. The spectrometer records the spectrum and sends the data back to earth. The instrument not only acquires spectra from Martian dust, but more importantly, is deployed to distinct rocks where it analyzes the native rock composition for the first time. The spectrometer determines the chemical make-up of surface materials and can find most major elements except hydrogen. The approach used is to expose the Martian rock to high-energy particles with a known energy and to analyze the resulting energy spectra emitted by the sample.

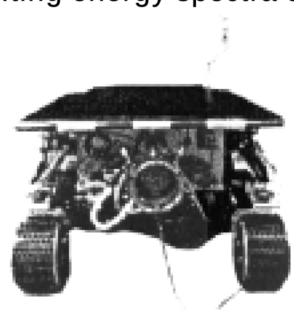


Figure 6-3: Front View of Spectrometer Mounted on the Rover

Note For more information about the Mars Pathfinder Mission, check out the following web page: http://mpfwww. jpl.nasa.gov/default1.html

The study of spectra includes energy that is outside the visible region such as infrared and radio (less than 1.6 eV) and ultraviolet and x-rays (greater than 3.1 eV). The Sojouner uses x-ray spectra in many of its analysis.

Initial analyses of the spectra from rocks have identified a rock rich in silica — a quartz material found in sand. Such a rock could have been brought to the surface by volcanic activity or by a meteorite impact. A rock rich in silica could only be formed by repeated heating in an active crust of a planet. A second type of rock may be andesite - one of the most common types of lava found on Earth. Since some types of andesite only form in the presence of water, scientists are speculating that Mars may have had water in its interior about the same time life began on Earth about 4 billion years ago.

We have learned that spectra can be used to determine some of the properties of the atoms of a gas. The spectrum from each type of atom is unique, somewhat like the uniqueness of human fingerprints. Just as fingerprints can be used to identify people, spectra are used to identify atoms in materials. For example,

- Astronomers determine the elements in a distant star by analyzing its spectra.
- Crime labs use spectra to match samples of paint on hit-and-run victims and suspected cars.
- Historians and archeologists use spectra to determine the elements used in painting and pottery. By knowing when different cultures started using substances containing certain elements they can determine the age and origin of the object.
- Biologists use spectra to identify the presence and concentration of substances.

These differences in spectra are, in turn, related to the energy levels of electrons in the atoms. These energy levels are related to the interactions between electrical charges. Thus, the spectra and our representation of atoms with the energy diagram are very closely related. Much of our knowledge of the universe, ranging from the enormous scale of galaxies to the small scale of atoms, is built on the study of spectra and our knowledge of the energy transition in atoms.

Planet's Atmosphere Spectrum