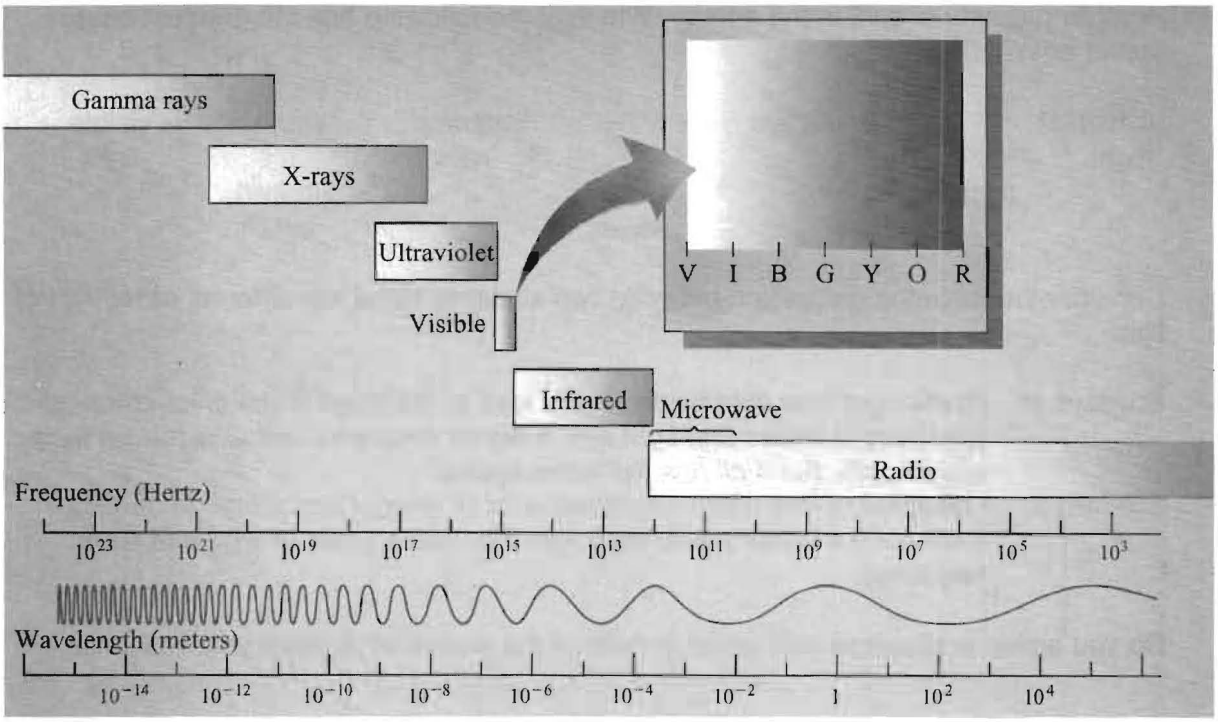


1) The electromagnetic spectrum of light is often arranged in terms of frequency. Which one of the following has the highest frequency (*circle one*)?

visible light | microwaves | infrared light | gamma rays | radio waves | X-rays | ultraviolet light

2) The electromagnetic spectrum of light can also be arranged in terms of wavelengths. Which one of the following has the longest wavelength (*circle one*)?

visible light | X-rays | ultraviolet light | infrared light | gamma rays | microwaves | radio waves

3) Which of the following types of light travels at the fastest speed (*circle your answer(s)*)? Explain your answer:

ultraviolet light | X-rays | gamma rays | visible light | microwaves | radio waves | infrared light

4) Another property of light is the energy. Which of the following has the greatest energy (*circle one*)?

ultraviolet light | X-rays | gamma rays | visible light | microwaves | radio waves | infrared light

5) Consider the following discussion between two students about the different properties of light.

Student 1: *I think I get how light works. If you look at the chart of the electromagnetic spectrum, it shows that light with a higher frequency will also have a long wavelength. But it all has the same speed.*

Student 2: *I disagree. If one type of light has a lot of energy and a high frequency, it will have a faster speed than light that has a lower energy and a low frequency.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

6) Complete the following sentence describing the relationship between the energy, frequency, and wavelength of light, using the words *highest, lowest, longest,* and/or *shortest.*

The portion of the electromagnetic spectrum of light with the ***greatest*** *energy has the _____ frequency and the _____ wavelengths.*

7) The visible light portion of the electromagnetic spectrum of light is often subdivided into the colors of red, orange, yellow, green, blue, indigo, and violet (*sometimes referred to as ROY G BIV*). Using the words *greatest, least, highest, lowest, fastest, slowest, longest,* and *shortest*, write a sentence or two that describes how light at the red end of the visible portion of the spectrum and light at the violet end of the visible light portion of the spectrum compare in terms of their energy, frequency, speed, and wavelength.

8) For each statement (a–d) provided below, circle the word choice that correctly describes how the two forms of light compare.

   a) Infrared light has greater / less energy than ultraviolet light.

   b) X-ray photons have longer / shorter wavelengths than gamma ray photons.

   c) Visible electromagnetic radiation has a higher / lower frequency than radio wave electromagnetic radiation.

   d) Infrared light has a faster / slower / same speed than microwave light.

9) Of all the types of light the Sun gives off, it emits the greatest amount of light at visible light wavelengths. If the Sun were to cool off dramatically and as a result start giving off mainly light at wavelengths longer than visible light, how would the frequency, energy, and speed of this light given off by the Sun also be different? Explain your reasoning.

Part I: Spectral Curves

White light is made up of all colors of light. We can see the individual colors when white light is passed through a prism or when we look at a rainbow. Light can come in an array of types or forms, which we call a *spectrum*. A *spectral curve* (like the one shown below) is a graph that displays the amount of energy given off by an object each second versus the different wavelengths (or colors) of light. For a specific color of light on the horizontal axis, the height of the curve will indicate how much energy is being given off at that particular wavelength. Figure 1 shows the spectral curve for an object emitting more red and orange light than indigo and violet. Notice that the red end of the curve is higher than the violet end, so the object will appear slightly reddish in color.

1) Which color of light has the greatest energy output in Figure 1?

2) Imagine that the blue light and orange light from the source were blocked. What color(s) would now be present in the spectrum of light observed?

3) Which of the following is the most accurate spectral curve for the spectrum described in Question 2?

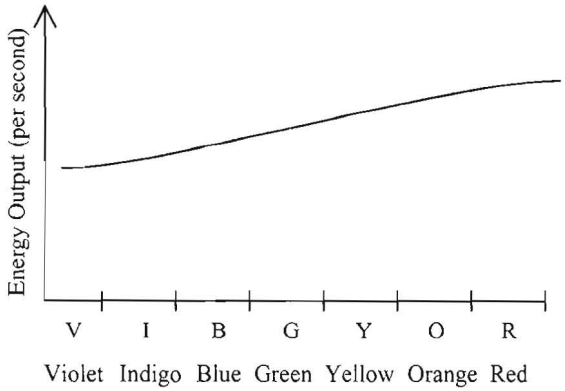
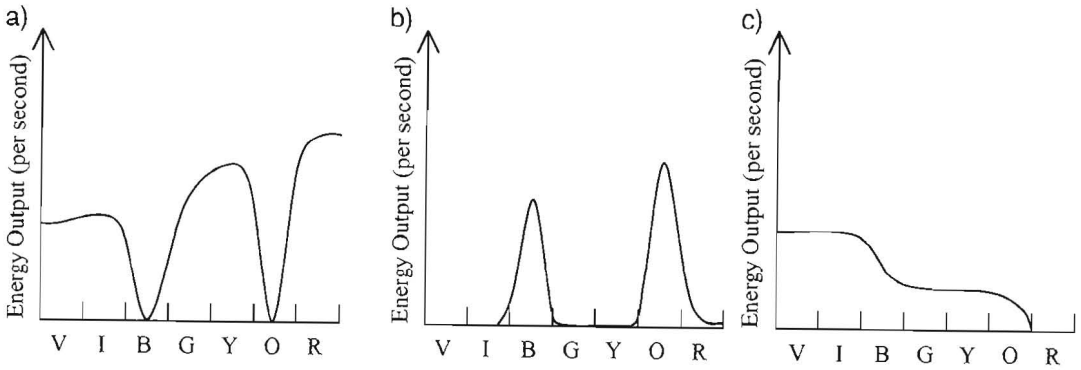


Figure 1



4) What colors of light are present in 3b above?

5) What colors are present in 3c above? Would this object appear reddish or bluish?

Part II: Blackbody Curves

Different colors of light are manifestations of the same phenomenon but have different wavelengths. For example, red light has a wavelength between 650 nm and 750 nm, whereas violet light has a shorter wavelength between 350 nm and 450 nm. Stars also give off light at wavelengths outside the visible part of the spectrum, as seen in Figures 2a, 2b, and 2c.

The two most important features of a star's spectral curve (also known as a blackbody curve) are:

- its maximum height or peak—where the energy output is greatest; and
- the corresponding wavelength at which this peak occurs—which indicates the star's temperature. If the peak occurs at a long wavelength, the star is cooler than a star that gives off most of its light (peaks) at a short wavelength.

For example, if Star E and Star F are the same size and temperature, they will have identical blackbody curves. However, if Star F is the same size as Star E, but is cooler, then its energy output is less at all wavelengths and the peak occurs at a longer wavelength (toward the red end of the spectrum).

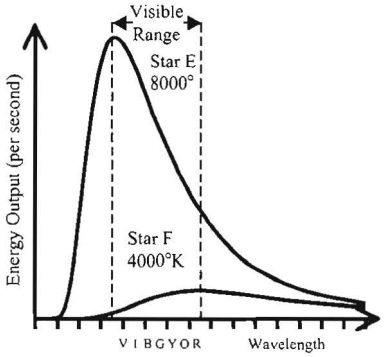


Figure 2a

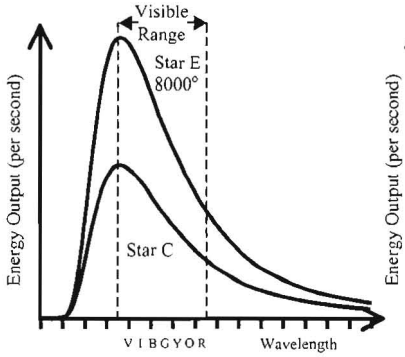


Figure 2b

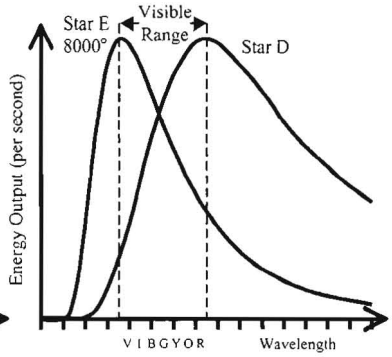


Figure 2c

Use Figure 2a to answer Questions 6–9. Assume Stars E and F are the same size.

6) Which star gives off more red light? Explain your reasoning.

7) Which star gives off more blue light? Explain your reasoning.

8) Which star looks redder? Explain your reasoning.

9) Two students are discussing their answers to Question 8.

Student 1: *Star E looks redder because it is giving off more red light than Star F.*
Student 2: *I disagree, you're ignoring how much blue light Star E gives off. Star E gives off more blue light than red light, so it looks bluish. Star F gives off more red than blue, so it looks reddish. That's why Star F looks redder than Star E.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

10) Using the blackbody curves shown in Figure 2b, for each characteristic listed in the table below circle the correct response in the column to the right.

Characteristic	Responses			
Peaks at a longer wavelength	Star E	Star C	They peak at the same wavelength	
Has a lower surface temperature	Star E	Star C	They have the same surface temperature	
Looks red	Star E	Star C	They both look red	Neither looks red
Looks blue	Star E	Star C	They both look blue	Neither looks blue
Has a greater energy output	Star E	Star C	The have the same energy output	

11) How must Star C be different from Star E to account for their difference in energy output? Explain your reasoning.

12) Two students are discussing their answers to Question 11.

Student 1: *The peaks are at the same place so they must be at the same temperature. If Star C were as big as Star E, it would have the same output. Since the output is lower, Star C must be smaller.*
Student 2: *No. If its output is lower, it must be cooler. Since the temperatures of the two stars are the same, they must be the same size.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

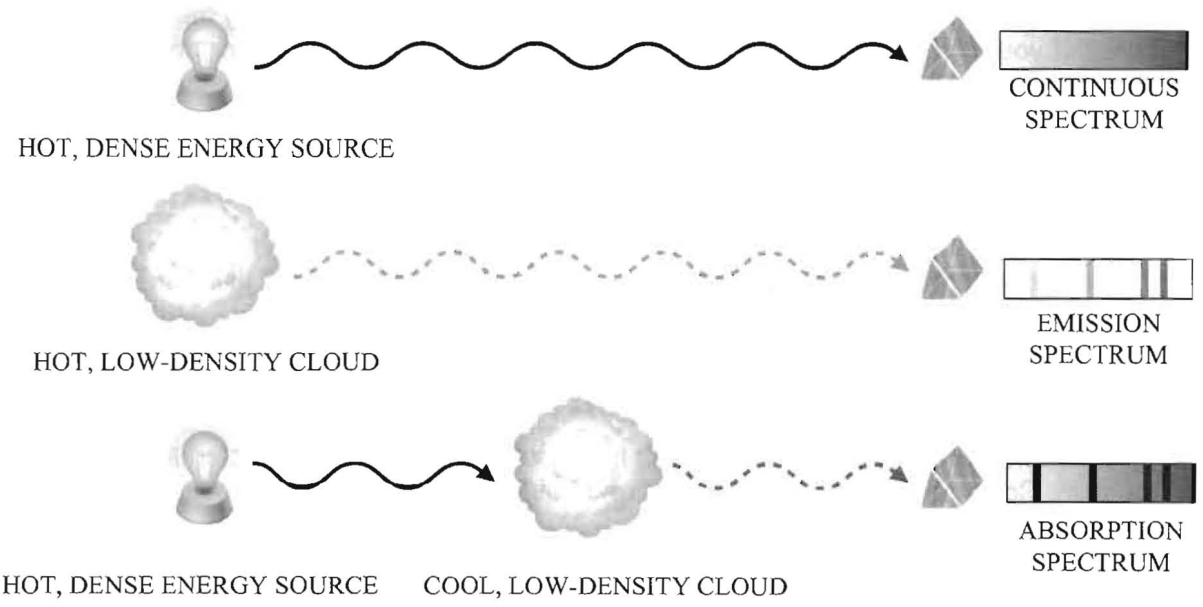
Consider the blackbody curves for Stars E and D shown in Figure 2c when answering Questions 13–15.

13) For each star, describe its color as either reddish or bluish.

Star E: Star D:

14) Which star has the greater surface temperature? Explain your reasoning.

15) Which star is larger? Explain your reasoning. (Hint: Consider how the energy output and temperatures for the two stars compare.)



1) What type of spectrum is produced when the light emitted directly from a hot, dense object passes through a prism?

2) What type of spectrum is produced when the light emitted directly from a hot, low-density cloud of gas passes through a prism?

3) Describe in detail the source of light and the path the light must take to produce an absorption spectrum.

4) There are dark lines in the absorption spectrum that represent missing light. What happened to this light that is missing in the absorption line spectrum?

5) Stars like our Sun have low-density, gaseous atmospheres surrounding their hot, dense cores. If you were looking at the spectra of light coming from the Sun (or any star), which of the three types of spectrum would be observed? Explain your reasoning.

6) If a star existed that was only a hot, dense core and did **NOT** have a low-density atmosphere surrounding it, what type of spectrum would you expect this particular star to give off?

7) Two students are looking at a brightly lit full Moon, illuminated by reflected light from the Sun. Consider the following discussion between the two students about what the spectrum of moonlight would look like.

Student 1: *I think moonlight is just reflected sunlight, so we will see the Sun's absorption line spectrum.*

Student 2: *I disagree. An absorption spectrum has to come from a hot, dense object. Since the Moon is not a hot, dense object, it can't give off an absorption line spectrum.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

8) Imagine that you are looking at two different spectra of the Sun. Spectrum #1 is obtained using a telescope that is in a high orbit far above Earth's atmosphere. Spectrum #2 is obtained using a telescope located on the surface of Earth. Label each spectrum below as either Spectrum #1 or Spectrum #2.

Spectrum #_____

Spectrum #_____

Explain the reasoning behind your choices.

In this activity, we will use a representation of the atom in which a central nucleus containing the protons and neutrons is surrounded by circles that represent the energy levels electrons can occupy.

1) Draw an atom including a nucleus and five energy levels that electrons could occupy. Use a dot to represent an electron at the lowest energy level.

One way an atom emits light (photons) occurs when an electron drops down from a high energy level (also referred to as an excited state) to a lower energy level (the lowest energy level is referred to as the ground state.)

2) Will an atom emit light if all of the atom's electrons are in the ground state? Explain your reasoning.

3) In which case does an atom emit more energy (*circle one*)?

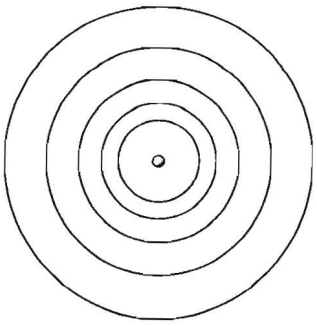
Case A: *An electron drops down from the first excited state to the ground state.*
Case B: *An electron drops down from the third excited state to the ground state.*

Explain your reasoning.

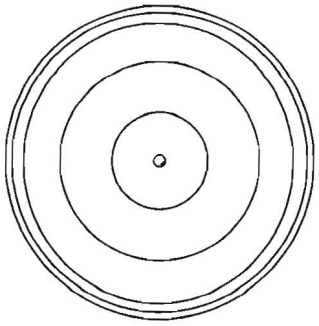
4) Two students are talking about how light is emitted from atoms. Consider the following discussion between the two students and the sketches each student drew to illustrate their thinking.

Student 1: *I drew my atom like this because my professor said that the gap between the energy levels gets bigger and bigger as you go up in energy from the ground state.*

Student 2: *I think you've got it backward. The gap between energy levels will get smaller as you go up in energy levels, like I've drawn.*



Student 1 Drawing



Student 2 Drawing

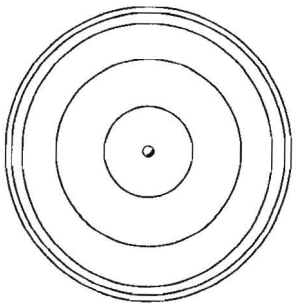
Do you agree or disagree with either or both of the students? Explain your reasoning.

5) A solid, glowing-hot object will emit light over the full range of wavelengths resulting in a continuous spectrum. If a diffuse and relatively cool cloud of gas is located between the glowing, hot object and an observer, what type of spectrum will the observer detect coming out of the cloud (*circle one*)?

continuous spectrum absorption spectrum emission spectrum

Explain the reasoning behind your choice.

6) At the right is a sketch showing one of the atoms in the diffuse, cool cloud of gas described in the previous question. Note that the atom has several energy levels that an electron could exist in. Using a dot to represent an electron, a straight arrow to represent the motion of the electron, and a squiggly arrow to represent the photon, sketch what you think would happen within this atom to cause the type of spectrum described in the previous question. Explain the reasoning behind why you drew the electron and arrows the way you did.

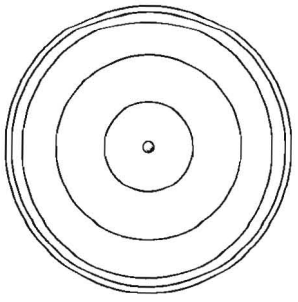


7) Imagine that you are looking at a neon sign in a store window that says "OPEN." This sign can be thought of as a tube filled with a gas of neon atoms that have electrons changing from one energy state to a different energy state and in the process are giving off mostly red light. Which type of spectrum would you observe coming from the "OPEN" sign (*circle one*)?

continuous spectrum absorption spectrum emission spectrum

Explain the reasoning behind your choice.

8) At the right is a sketch showing one of the atoms in the neon sign described in the previous question. Note that the atom has several energy levels that an electron could exist in. Using a dot to represent an electron, a straight arrow to represent the motion of the electron, and a squiggly arrow to represent the photon, sketch what you think would happen within this atom to cause the type of spectrum described in the previous question. Explain the reasoning behind why you drew the electron and arrows the way you did.



9) Consider the following discussion between the two students about the atoms and light coming from the red "OPEN" sign from the previous question and the light coming from a yellow "OPEN" sign they see across the street.

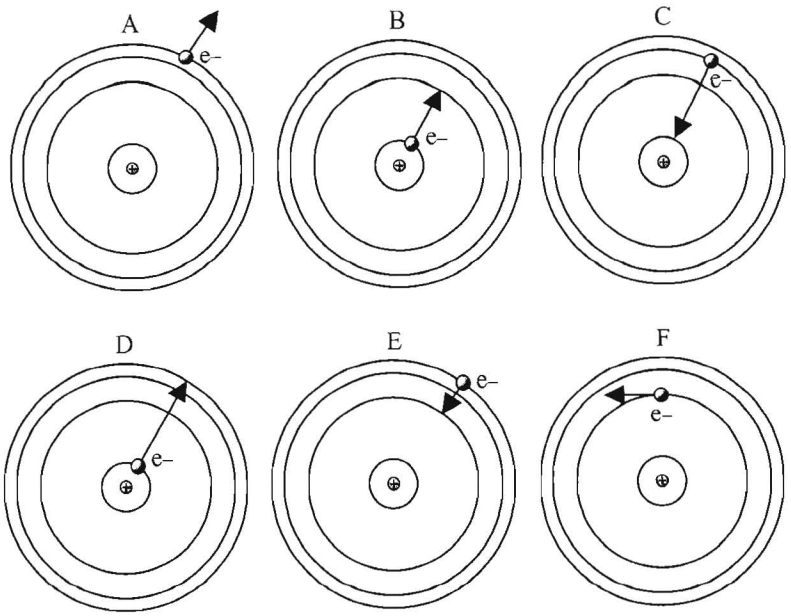
Student 1: *I think that all you need to do to get signs to give off light of different colors is to use tinted glass of different colors. If you electrify a gas, white light is emitted so the color of glass gives the sign its color.*

Student 2: *That can't be it because the electrons will always move between the same energy levels for atoms in a neon sign and so they will mostly give off red light. I think the yellow sign is filled with a different type of atoms with energy levels that are farther apart, so when the electrons drop down from a higher energy level to a lower energy level, the atoms will give off yellow light instead of red light.*

Do you agree or disagree with either or both of the students? Explain your reasoning.

10) Redraw the initial drawing you made in Question 1. Describe what additions or changes you made on this new drawing so that it better conveys what you understand about the relationship between light and atoms.

11) Use the hypothetical atom drawings (A–F) below to answer the next five questions. Note there is only one correct choice for each question and each choice is used only once.



a) Which shows the absorption of violet light? Explain your reasoning.

b) Which shows the emission of blue light? Explain your reasoning.

c) Which shows the absorption of green light? Explain your reasoning.

d) Which shows the emission of orange light? Explain your reasoning.

e) Which shows an electron being ejected from the atom?