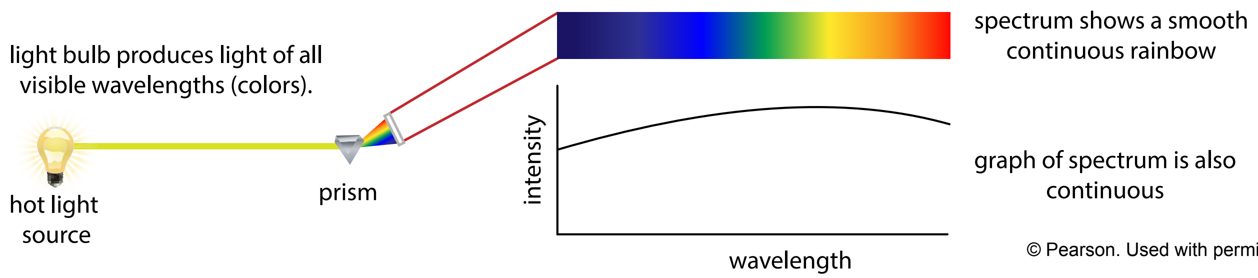
I like nonsense, it wakes up the brain cells. Fantasy is a necessary ingredient in living, it's a way of looking at life through the wrong end of a telescope. Which is what I do, and that enables you to laugh at life's realities.

Dr. Seuss

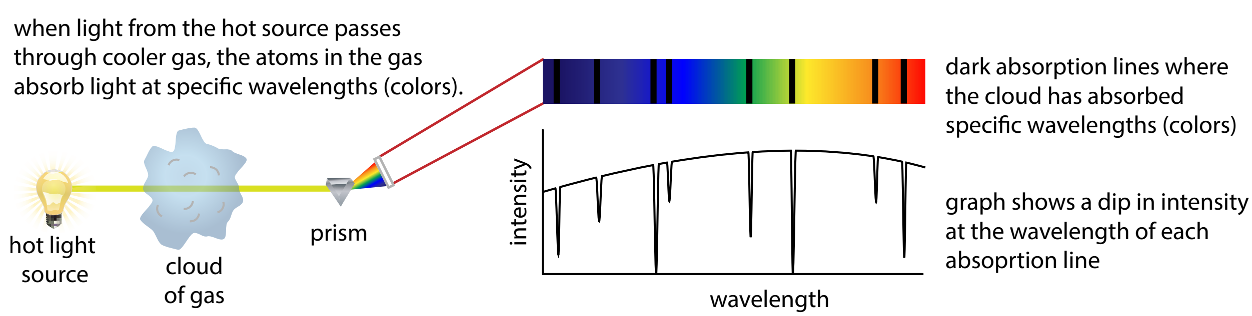
Rainbows With Holes

Greetings. In this module we're going to cover the three different types of spectra. We're going to combine our knowledge about what is light, what is matter, and how matter stores energy. We'll talk about the three basic types of spectra, and then finally, how does light tell us what things are made out of.



continuous spectrum

There are basically three types of spectra. First is a continuous spectrum, which looks like a rainbow. An example is shown above. If you take a bright light source and put it through a prism, you get a rainbow, a continuous spectrum. They're all there, from purple through blue, green, yellow, orange, and red. A continuous spectrum.

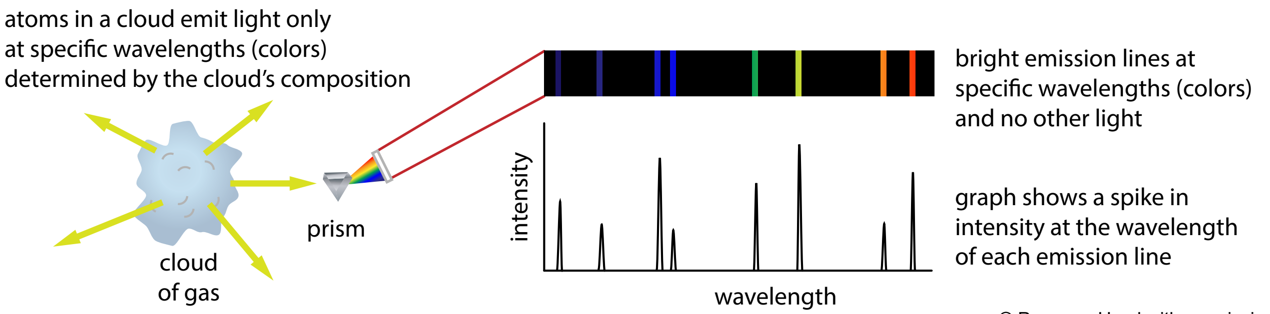


absorption spectrum

Now if you take that same light source and you put a cloud of cooler gas in front of it — like the light bulb would be the center of the Sun, that cloud of cooler gas is the atmosphere of the Sun, the photosphere of the Sun — you get the rainbow alright but now you get all these dark lines punched into it. Rainbows with holes. And those holes, those lines, are coming from the absorption of energy at a particular wavelength, at a particular color, by the atoms in the cloud.

This goes back to the energy levels of atoms, of only taking energy at very particular energies, very particular colors, as electrons move from one excited state to another excited state. So what you're seeing there in those dark lines is the absorption of photons by atoms. Of course, there's a lot of atoms and there are a lot of photons. You're not seeing one individual photon and one individual atom. It is the cumulative effect of all of them. That's why you can see it. We're watching atoms collectively do their thing!

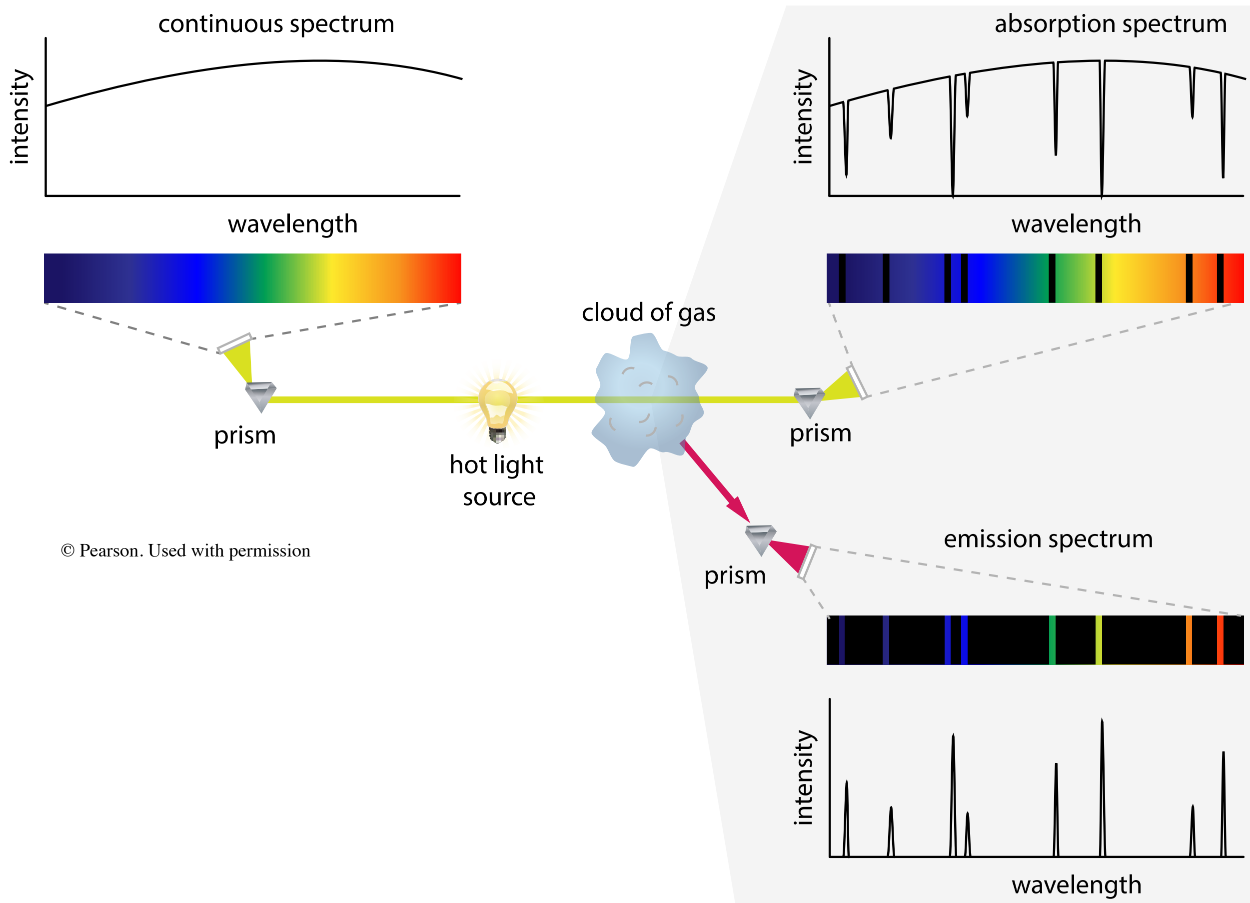
I hope it is clear as to why we're getting those dark lines. You're seeing the absorption of energy. That energy is going into raising the energy level of an electron, let's say, from the ground state up to the first excited state, or whatever it may be. This is the absorption line spectrum.



emission spectrum

Now you have your hot light bulb, your hot light source. You've also got your cloud of gas in front of your hot light source. Now look at the cloud again, but without the hot light source, as shown in the illustration above. Sort of like looking at the cloud from a grazing angle, if you like. What you see is called an emission line spectrum. You only see the light with very specific colors against a black background. The black background is there because you're not looking at the light source. You're looking away from the light source through the cooler cloud of gas.

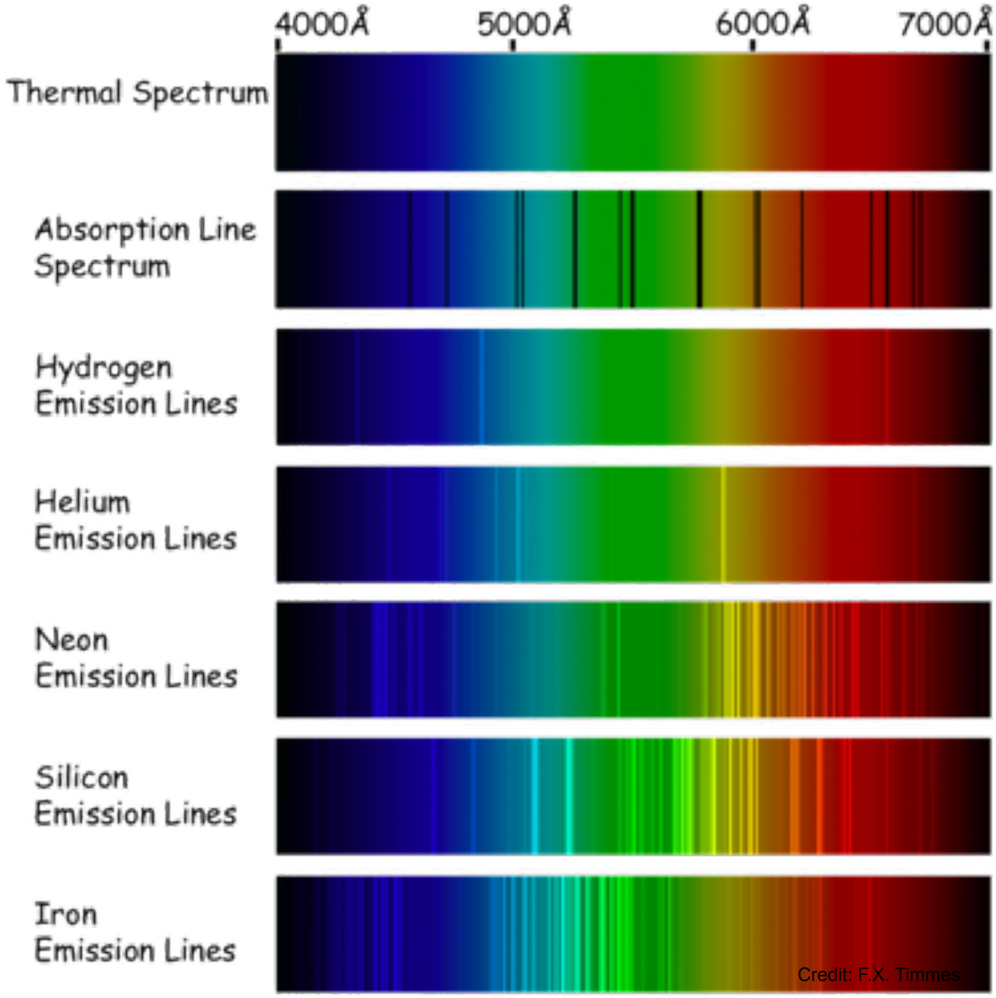
Those bright emission lines are -- surprise! -- in exactly the same locations, and colors, as the absorption lines we had in the absorption line spectrum. What you're looking at is the process of electrons falling from an excited state back to a lower energy state. And in doing so a photon of a very specific energy, a very specific color, is emitted. You see this de-excitation as the emission line. Since these are the same atoms that absorbed those specific wavelengths when light from your hot source went through the cloud, this de-excitation releases photons at the same wavelengths.



So to summarize, we have three types of thermal spectrum. You have hot object emitting a continuous spectrum. We'll talk later about what a thermal spectrum is, but we'll just say the words now. A hot object emits a continuous thermal spectra. You get the rainbow of color when you look with nothing between you and the light source.

Now if you look at the light source through a cloud of cooler stuff, you see an absorption line spectrum. And if you look at the cloud, but not at the central source, the light bulb in this case, you see an emission line spectrum. The absorption line and emission lines occur at exactly the same wavelengths, the same colors. So that if you sum them up, if you took that absorption spectra and added it to the emission line spectra, you would get back the continuous spectra.

It's conservation of energy in action! You're taking some energy away in the absorption line spectrum, and it comes out in the emission line spectra in exactly the same locations. So the total energy is conserved, as it flows through the cloud. So learn these three spectra types. They're important. Yes this will be on the test.



How does light — our massless spaceships traveling at the speed of light — tell us what things are made of? Well, emission or absorption lines only occur at very specific wavelengths, very specific colors. And they correspond to very specific energy level transitions in atoms and/or molecules.

The key is that atoms of different elements have a unique pattern of energy level transitions. So atoms of different elements have a unique pattern of absorption line or emission line features. So when you see these features in a spectrum, they're like an old friend. You can look say ah! That's hydrogen. I recognize hydrogen because it's got these lines at these particular locations. Similarly, for all the other elements. It’s like a fingerprint.

The image above shows a few examples of what some of these fingerprints look like. At the top, there's a thermal spectrum, a continuous rainbow. Below that we have an absorption line spectrum and then an emission line spectrum of hydrogen. There are not many lines in the emission line spectrum for hydrogen, because there's only one electron.

Helium has more lines because there are more electrons. Neon, from neon light fame, has more electrons. You'll notice most of the lines are in the red part of the spectrum - neon lights. To get up to iron you need a lot of electrons — 26. So there are a lot of transitions in the emission line spectrum.

So we can determine the composition of an object by noting where these lines occur and by recognizing old friends. Hey, this is carbon. This is silicon.

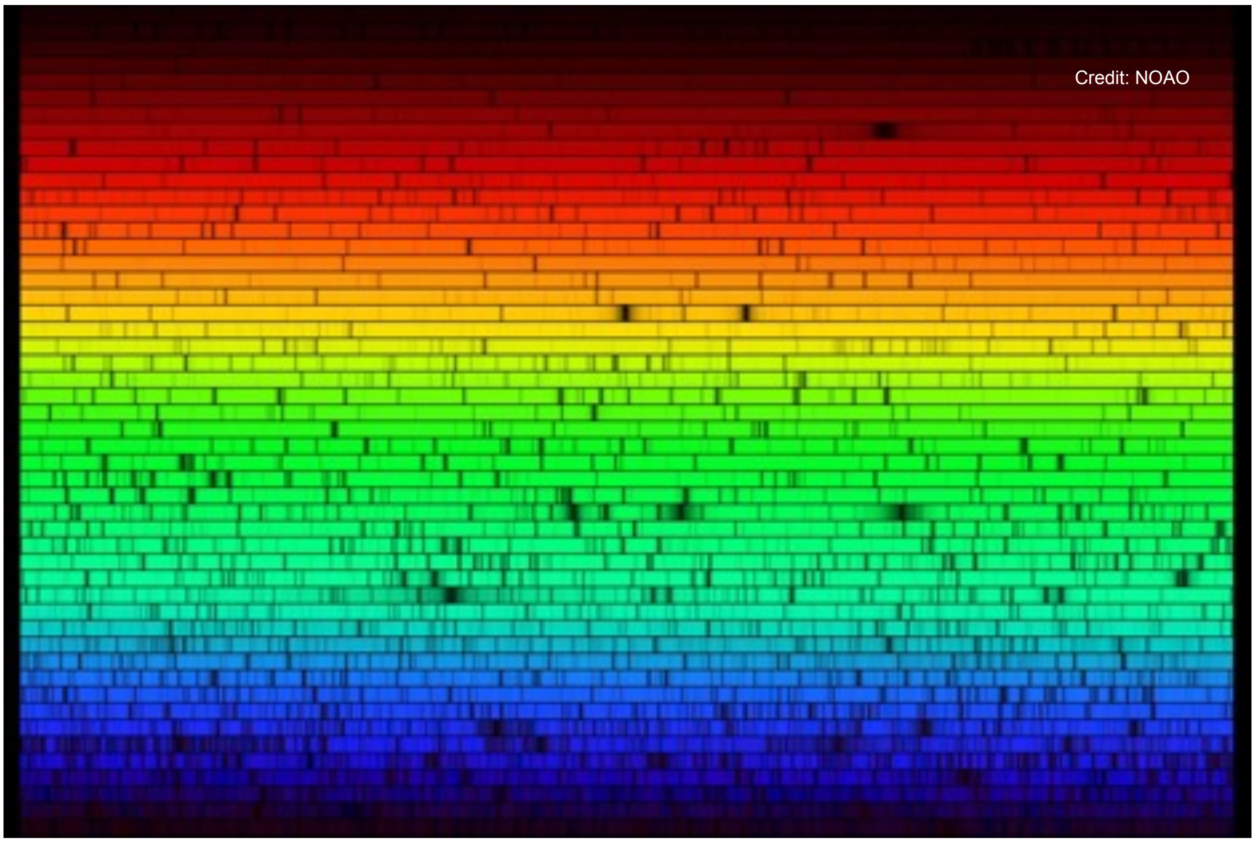
This is exactly what they do in a forensic lab, when they want to know what something is made out of. Perhaps they have a piece of paint from a crime scene. They want to know what's in that paint so that they can trace it back to the manufacturer who sold it, and begin the crime investigation. They take a little piece of that paint and burn it. When it burns, light comes off of the hot paint. They take the light from that hot paint and break it into its component colors. They then take a look at where the absorption line or emission line features occur and can identify the elements that are in that light. And hence, they know exactly what the paint chip was made of.

Molecules kind of do the same thing. They also have electrons going up and down. But molecules, because they're composed of two or more atoms, give you additional motions and additional degrees of freedom that an atom can't.

First, if you've got two atoms in a molecule, you can rotate the thing. This gives new transitions, new lines. Second, you can kind of think of the bonds between atoms in a molecule as springs, and you can vibrate those springs. You can shake it back and forth. Both of these give rise to new ways to store energy, either in vibration or in rotation. You get the same sort of features in spectra from these modes, except now, they're all kind of bunched together because the energy differences are small. These features are called molecular bands.

So what does a real spectrum from a real object look like? Below is the spectrum of the Sun. You see rainbows with holes, an absorption line spectra. You see the rainbow because the inside of the Sun is hot, emitting a continuous thermal spectrum. Then the atoms in the outer layers of the Sun absorb some of the energy to promote electrons from a low energy level to a higher energy level. By identifying the unique pattern of lines associated with different elements, we can tell what the Sun is made of.

For example, the element helium (root word helios, meaning Sun) was discovered in 1866 by looking at the spectra of the Sun during an eclipse. It was not until some 30 years later that the helium and its spectra were generated in a terrestrial laboratory. Helium, the second most abundant element in the universe, has only been known for about 150 years!



Thanks! for listening. Bye bye!