AST 301
Introduction to Astronomy

John Lacy
RLM 16.332
471-1469
lacy@astro.as.utexas.edu

Myoungwon Jeon
RLM 16.216
471-0445
myjeon@astro.as.utexas.edu

Bohua Li
RLM 16.212
471-8443
bohuali@astro.as.utexas.edu

web site: www.as.utexas.edu
Go to Department of Astronomy courses,
AST 301 (Lacy), course website

Topics for this week

What is a photon? What is an electromagnetic wave?

How are the photon and wave pictures of light related?

Make a sketch of an atom, showing its parts.

How do the wave properties of electrons result in only certain electron orbits being allowed in an atom?

How does the fact that only certain electron orbits can occur result in photons of only certain wavelengths being emitted?

Describe emission and absorption line spectra and the conditions under which each occurs.

Describe black body radiation and the relations between temperature and the power emitted and the wavelengths of light emitted.

Describe the Doppler shift.

AST 301
Test #1
Friday Sep. 17 Name:_____

1. Define these words:

a) Universe

everything everywhere
includes planets, stars, galaxies

b) celestial equator

an imaginary line around the celestial sphere above the Earth's equator
half way between the celestial poles

c) sidereal day

a star day
the time from when a star rises (or sets) until the next time it rises (or sets)
it's a bit shorter than a solar day

2. a) Why is it hotter in Austin in June than it is in December?

The Earth is at the place in its orbit where the northern hemisphere is tipped toward the Sun. This means that the Sun passes closer to overhead in June, so it shines more straight down on the surface of the Earth, rather than at an angle. It also is above the horizon longer.

b) Why do we see different constellations at night in June and in December?

We are at a different place in our orbit. We can't see the stars behind the Sun since they are up in the daytime. So we see the stars that are on the opposite side of the Earth from the Sun.

3. a) How has Venus moved in the sky relative to Spica over the last few weeks?
It has fallen behind Spica. It was leading Spica across the sky. It now trails Spica. Put differently, it has moved to the east of Spica, or it has moved west to east relative to Spica.
b) Venus will be moving retrograde next month. How will its motion differ then?
It will start catching up with Spica. That is, it will move east to west faster than Spica does.

4. a) The Moon will be full on Thursday of next week. At about what time of day or night will it rise then?
It will be on the opposite side of the Earth from the Sun, so the Sun is lighting up the face we see. So it will be high in the sky near midnight, and so it must rise around sunset.
b) If there is an eclipse next Thursday, which type of eclipse (solar or lunar) will it be? Explain how you figured that out.
It would have to be a lunar eclipse, since with the Moon opposite the Sun, the Earth's shadow could be cast on the Moon. (There wasn't actually an eclipse since the Earth's shadow passed above or below the Moon.)

5. How did Kepler's model of the solar system differ from Copernicus' model? Give at least two differences.

1. Kepler had the planets moving on ellipses instead of circles (or actually modified circles).
2. Kepler had accurate formulas for how fast the planets moved. In particular, he knew how the planets' speeds varied from place to place in their orbits and how the orbital periods depended on the average distance from the Sun.

(They both had heliocentric systems, and both said that the reason for retrograde motion was that the inner planets move faster than the outer planets.)

6. Assume my little eraser has a mass of 1 kg and my big eraser has a mass of 2 kg.

a) How does the force of gravity on the two erasers compare? (For which is it greater, and how many times greater, or are they the same?)

The force of the Earth's gravity on an eraser is proportional to its mass, so it is twice as large on the 2 kg eraser. (Although the acceleration of gravity is the same for the two erasers. That's because a larger force is needed to move a more massive object – see part b.)

b) If I push on the two erasers with the same force (and there are no other forces acting on them, not even gravity) how will their motions compare?

$a = F/m$, so the same force will cause a greater acceleration (and greater speed) for the smaller mass. The 1 kg eraser will move more.

Spectra of gasses and solids

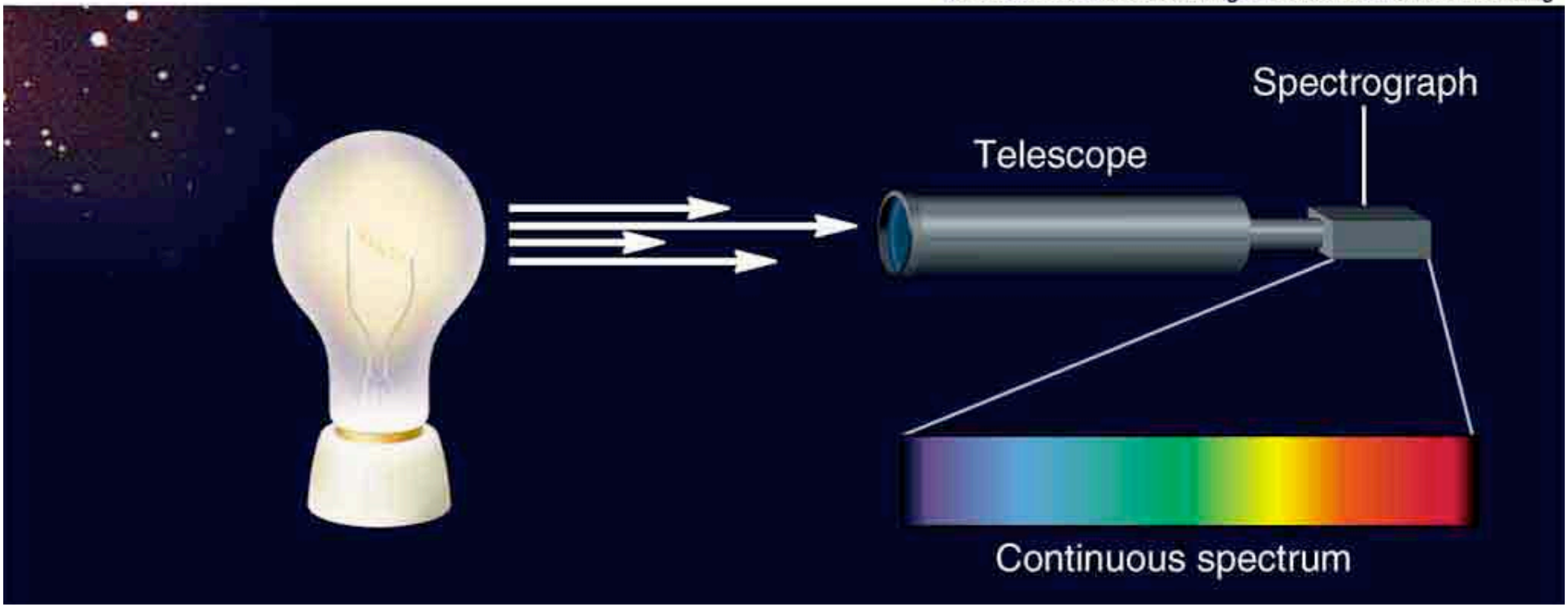
When solids are heated they emit all wavelengths of light (a continuous spectrum).

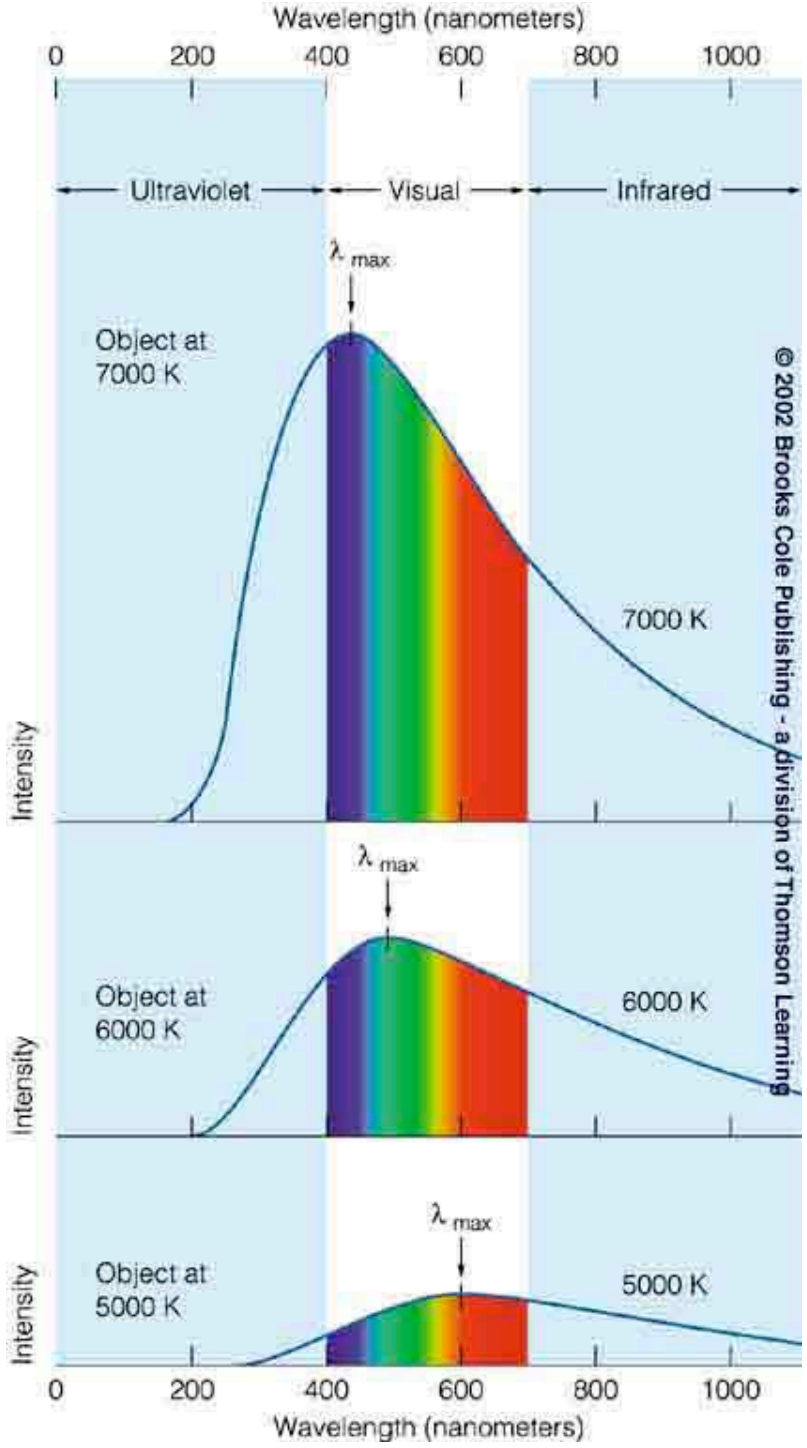
How bright the light at different wavelengths is depends on the temperature of the solid. Hotter solids emit more light of all wavelengths, but they especially emit more short wavelength (blue and violet) light.

When gasses are heated they emit only certain wavelengths of light (an emission line spectrum).

Different gasses emit different wavelengths.

A cool object (gas or solid) can absorb some of the light passing through it.





Hot solids – continuous spectra

The temperature of an object is a measure of how much energy its atoms have.

Since atoms in hotter objects have more energy, they can emit photons with more energy than cooler objects can.

(When an atom emits a photon the photon energy comes from the atom, so an atom can't emit a photon with more energy than the atom had.)

So hot objects emit high energy photons, or short wavelength light.

Since $\lambda \propto 1/E_{photon}$ and $E_{photon} \sim E_{atom} \propto T$, $\lambda \propto 1/T$

They also emit more photons that cooler objects do.

The rule is the amount of power emitted (energy emitted each second) is $P_{emitted} \propto T^4$

Quiz

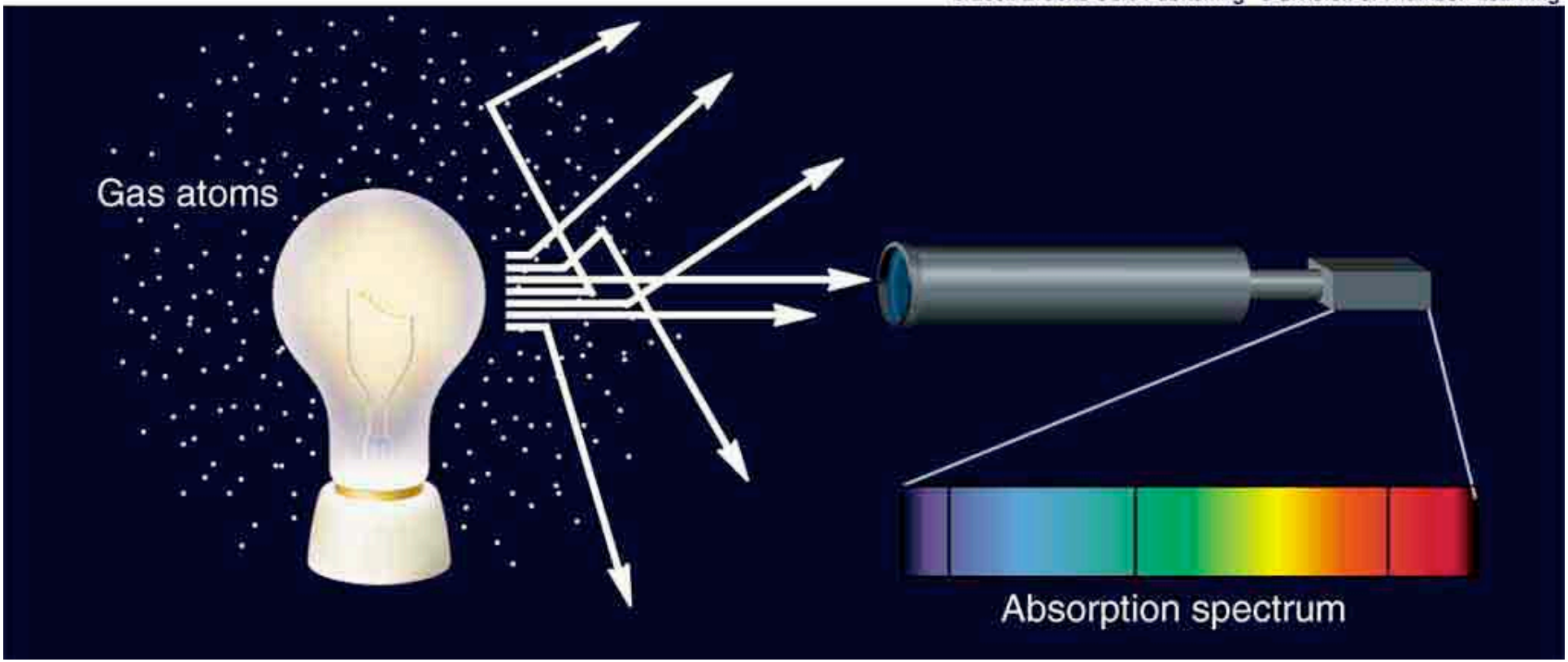
When you look at a light bulb through a piece of red plastic, the light looks red. This is because:

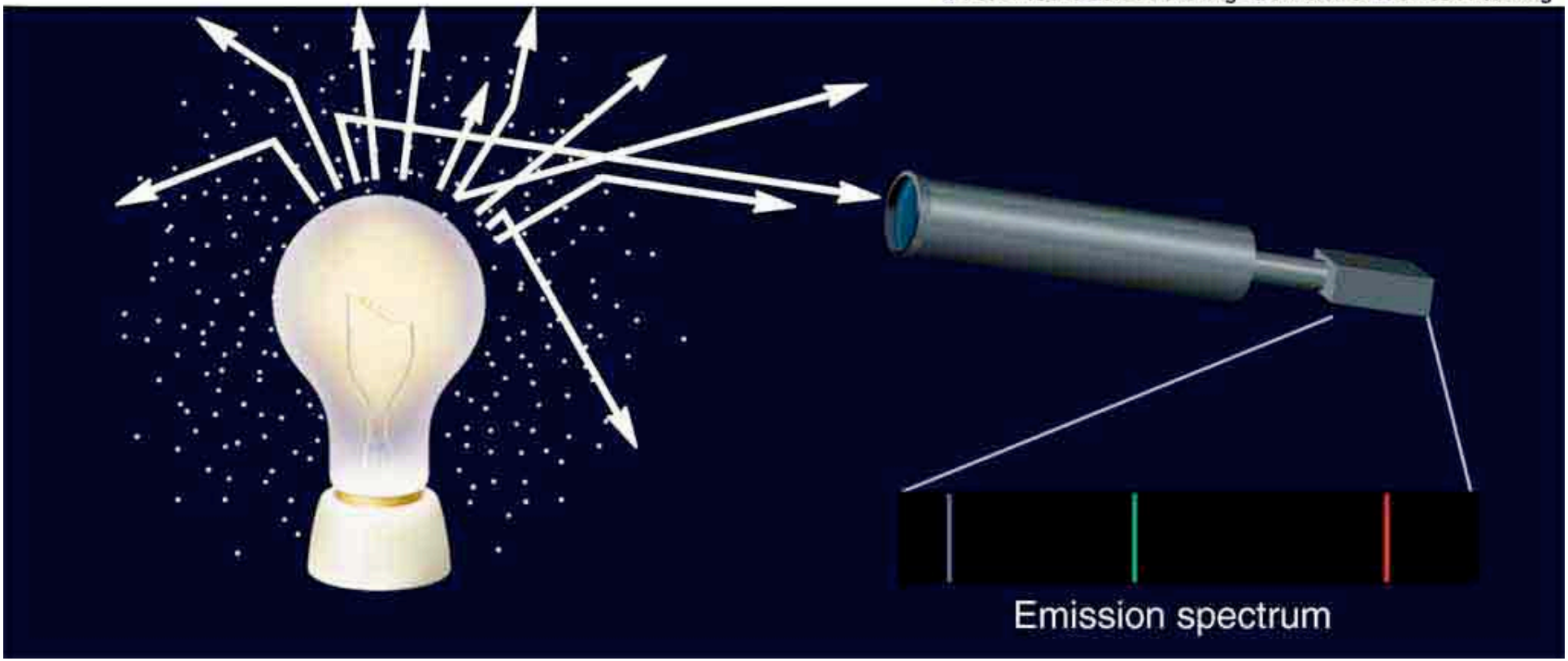
A. The plastic absorbs the white light from the bulb and emits red light.

B. The plastic shifts all of the photon wavelengths toward the red end of the spectrum.

C. The plastic absorbs the green photons and converts them into red photons.

D. The plastic absorbs the green photons, leaving the red.





Emission line spectra

Hot gas emits light of only certain wavelengths.

If a source emitting a continuous spectrum lies behind cool gas, the gas absorbs some of the light, and it absorbs the same wavelengths of light that it would emit if hot.

To understand why gasses act this way, we need to understand more about how electrons orbit in atoms.

What is an atom?

A hydrogen atom has one proton at its center, with one electron orbiting around the proton.

The proton has a positive electrical charge.

The electron has a negative charge and is about 2000 times less massive than the proton.

Opposite charges attract, with a force law like that for gravity, so we expect the electron orbit to obey laws like Kepler's laws.

Other atoms have additional protons in their nuclei and additional electrons orbiting around their nuclei.

The also have neutrons (electrically neutral particles with masses similar to proton masses) in their nuclei.

Electron waves

We normally think of electrons as particles.

But like photons, they have both wave and particle properties.

The height of the wave describes the probability of finding the electron in different places.

The wavelength of the probability wave is related to the electron speed, v, by:

$$\lambda = h / mv,$$

where h is Planck's constant and m is the electron mass.

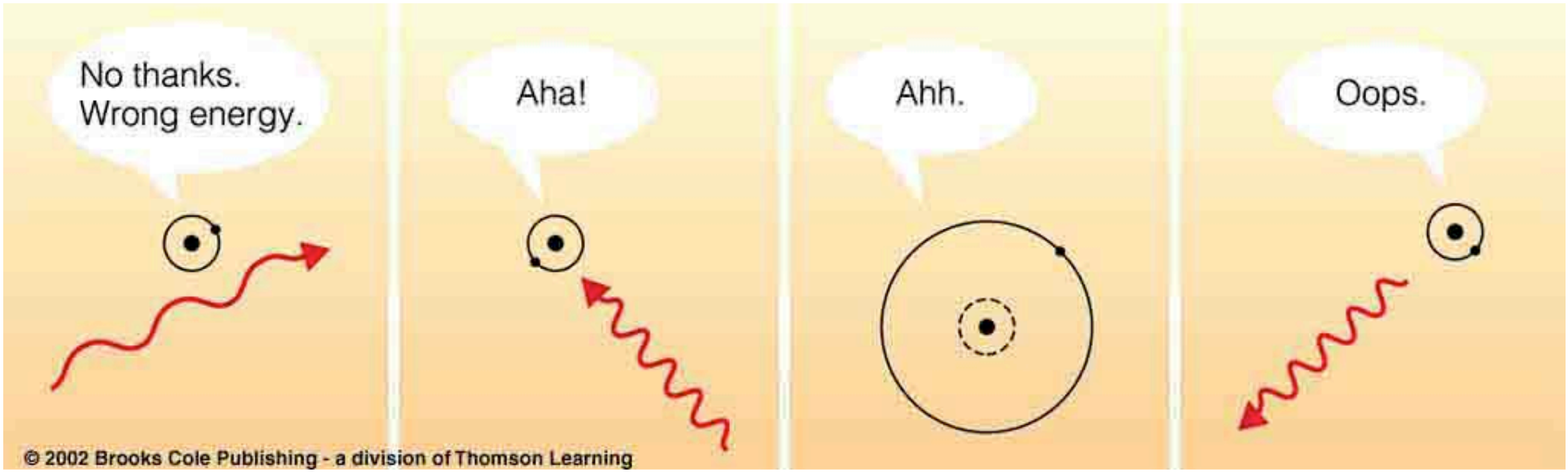
In an atom, an electron must orbit at a distance from the nucleus so that an integral number of probability waves fit around its orbit.

This causes only certain electron speeds or energies to be allowed.

Emission and absorption of light by atoms

When an atom absorbs light, the photon energy must equal the energy needed to make an electron jump from a small orbit to a bigger one.

When an atom emits light, a photon is created, and the energy of the photon must equal the energy lost by the atom when an electron jumps from one orbit to another.



A big jump for an electron requires a high energy photon, or short wavelength light.