Unit 4 Study Guide
Spectroscopy

Targets:

E1. *Trace the development of models of the atom to the present and describe how each model reflects the scientific understanding of their time.*

G1. *Describe how scientists gather data about the universe.*

Activity #1 – Powers of Ten

Open Secret Worlds: The Universe Within

Scientists look at things in very particular ways using sophisticated equipment, everyday instruments, and unlikely tools. Some things that scientists want to see are so small that they need a magnifying glass, or a microscope. Other things are so far way that they need a powerful telescope in order to see them. It is important to understand and be able to compare the size of things we are studying.

Exponential notation is a way scientists write very large or very small numbers. For example, when the Earth is seen at 10^6 meters wide, this number represents 1,000,000 meters. When a nucleus of a cell is seen at 10^{-6} meters wide, this number represents one millionth of a meter, or 0.000001 meters. Notice how each picture in this simulation is an image of something that is 10 times bigger or smaller than the one before or after it. The number on the right is the size of what is seen in the picture. The number on the left is the same number written in powers of ten, or ***exponential notation***.

In this simulation you will first view the Milky Way at 10 million light years from the Earth. Then move through space towards the Earth in single order of magnitudes until you reach an oak tree just outside the National High Magnetic Field Laboratory in Tallahassee, Florida. Then begin to move from the actual size of a leaf into the microscopic world through leaf cell walls, cell nucleus, DNA and finally, into the subatomic universe of electrons and protons. You will then manually reverse the direction, moving from smallest to largest value, as you log your power of ten journey.

Activity: Log your "Power of Ten" journey into the universe by completing this table describing your journey. Hopefully, you will be able to appreciate the powers of ten used in exponential notation and learn a few metric prefixes along the way. Start small and manually move to the larger Exponential values. Have a safe journey!

Power of Ten	Description	Location
10^{-15}	1 fermi	Face to Face with a single Proton
10^{-14}		
10^{-13}		
10^{-12}		
10^{-11}		
10^{-10}		
10^{-9}		
10^{-8}		
10^{-7}		
10^{-6}		
10^{-5}		
10^{-4}		
10^{-3}		
10^{-2}		
10^{-1}		
10^{0}		
10^{1}		
10^{2}		
10^{3}		
10^{4}		
10^{5}		
10^{6}		

10^7		
10^8		
10^9		
10^{10}		
10^{11}		
10^{12}		
10^{13}		
10^{14}		
10^{15}		
10^{16}		
10^{17}		
10^{18}		
10^{19}		
10^{20}		
10^{21}		
10^{22}		
10^{23}		

1) Which of the smaller Power of Ten images presented are your eyes actually able to observe as you stand on the earth's surface (without optical assistance).

   a) As small as ____________________ (state a power of ten value)

   b) Describe the image you selected:

2) Which of the larger Powers of Ten images marks the greatest distance humans have ventured away from planet Earth?

   a) As large as ___________________ (state a power of ten value)

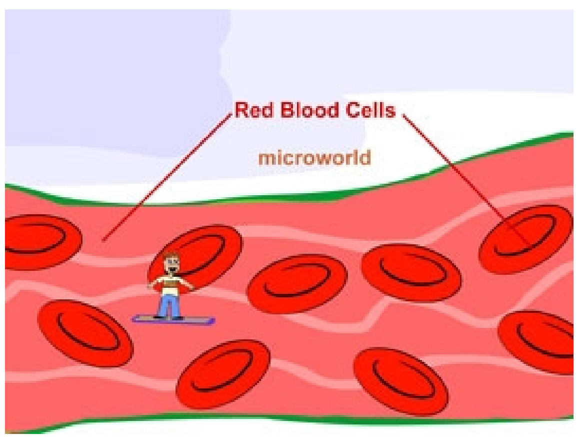
   b) Describe the image you selected:

3) In terms of light-years, how wide is the Milky Way Galaxy? _____________ light-years

Activity #2 The Metric System and Metric Prefixes

When the metric system was devised in the late 1700's there was no particular need for very large or very small numbers. It was already customary to count in thousands and millions, and to use commas to set off the extra zeros in groups of three, as we still do today. In the two centuries since that time we have learned to measure objects and distances, both large and small, to the limits of nuclear particles and astronomical bodies, and to count from pennies to the US national debt.

In the metric system, metric prefixes are used to represent powers of 10. For example, instead of writing *1,000,000,000,000,000 meters* you could write *1 petameter*. **Peta-** mean 10^{15}, so 1 pm = 10^{15} m.



How small is a nanometer? Click the pic for a movie!

Open Metric Prefixes and fill in the chart below.

Prefix:	**Symbol:**	**Power of 10:**	**Number Meaning (multiply by):**
		10^{15}	
		10^{12}	
		10^{9}	
		10^{6}	
		10^{4}	
		10^{3}	
		10^{2}	
		10^{1}	
none	none	10^{0}	1
		10^{-1}	
		10^{-2}	
		10^{-3}	
		10^{-6}	
		10^{-9}	
		10^{-12}	
		10^{-15}	
		10^{-18}	

Metric prefixes all represent powers of ten and can be put in front of any word.

1) How many meters are in a kilometer as a

   a) number?

   b) power of ten?

2) In “Back to the Future", a gigawatt lightning bolt played a big part in getting the time machine to work. How many watts are in a gigawatt as a

   a) number?

   b) power of ten?

3) What is one word that would mean the same as

a) 10^{12} bulls = 1 __________ bull
b) 10^{6} phones = 1 __________ phone
c) 10^{1} cards = 1 __________card
d) 10^{9} lows = 1 __________ low
e) 10^{-12} boos = 1 __________boo
f) 2 X 10^{3} mockingbirds = 2 __________ mockingbirds
g) make up one of your own! be creative!

Activity #3: The Electromagnetic Spectrum

Open Death Star – Tour the Spectrum and fill in the blanks.

1) Light, heat, radio transmissions, and medical X-rays may not seem all that similar, yet they are all forms of ____________________ ____________________ -- waves moving through space (not just outer space) that have an ___________ and ____________ component and are delivered by massless particles called ______________. The only thing that differentiates one type of electromagnetic radiation from any other is the _____________ carried by its photons.

Open Death Star- What Are Electromagnetic Waves? and fill in the blanks.

2) Every photon is characterized by ____________________ (the distance from the crest of one wave to the crest of the next wave), by _____________________ (the number of wave cycles that pass by in a given period, measured in______________________, which stands for cycles per second), and by the ________________ it carries (measured in ___________________).

Open the Spectrum Applet. In this applet, you can left click on the blue line on the wavelength/frequency scale and drag it around to investigate different parts of the electromagnetic spectrum. In this applet, number written, an "e" followed by a number mean a power of ten raised to that power. For example, 2.014e-9 means 2.014 X 10^{9}.

3) What are seven listed types of electromagnetic radiation (EM radiation) illustrated in this applet? List them from left to right. The first one has been done for you.

gamma rays						

4) What are the two units used in this applet to measure

a) wavelength? ____________ ____________
b) frequency? ____________ ____________
c) energy? ____________ ____________

5) Move the blue line to the right and then to the left and see what happens to the frequency and energy as the wavelength increases and decreases, respectively. Fill in this sentence:

As the wavelength increases, the frequency _____________ and the energy ______________.

As the wavelength decreases, the frequency _____________ and the energy ______________.

6) Which electromagnetic radiation (EMR) has the largest wavelength? _____________

Which type of EMR has the smallest wavelength? _________________

Which has the largest wavelength:

- Radio waves or x-rays? _________________
- Infrared or Visible light (V)? ____________________
- Microwaves or Ultraviolet (UV) __________________
- Gamma or x-rays? ____________________________

7) AM radio stations broadcast at a frequency of kilohertz and FM radio broadcast at a frequency of megahertz. Using your metric prefixes list, fill in the blank with a power of ten.

- 1 kilohertz = _____ hertz
- 1 megahertz = _____ hertz

Which is bigger, a khz or a Mhz? _________

Which radio station has the longest wavelength? ______________ (AM or FM)

8) Which type of EMR has the most energy? ___________________

Which has the least energy? ______________________

Which visible color has the most energy? ___________

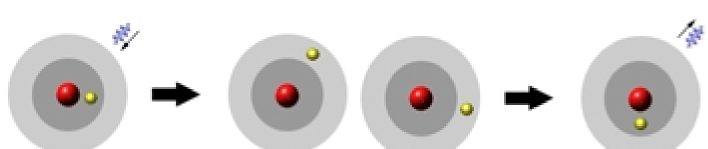
Which color has the least amount of energy? ____________________________

9) What type of EMR is it? From the following clues determine the EMR type and circle one item that relates to what this person is doing or being exposed to?

Wave Fact/Data	**EMR Type**	**Person's Activity (Select one for each row)**
10 angstrom wavelength (1 angstrom = 10^{-10} meters)		(Dental Exam) (Reading) (Listening to radio) (Tanning) (Cooking)
32 GHz frequency		(Dental Exam) (Reading) (Listening to radio) (Tanning) (Cooking)
10.8 meters wavelength		(Dental Exam) (Reading) (Listening to radio) (Tanning) (Cooking)
6.28 X 10^{-18} joules of energy		(Dental Exam) (Reading) (Listening to radio) (Tanning) (Cooking)
500,000 GHz frequency		(Dental Exam) (Reading) (Listening to radio) (Tanning) (Cooking)

<u>Activity #4: Spectral Lines and the Bohr Model of the Atom</u>

Nobody knows what an atom looks like, or even if it makes sense to suppose it has an appearance. To visualize the processes that occur at the subatomic realm, we construct models. In the planetary model - the one that most people think of when they picture the atom - the electrons orbit the nucleus like planets going around the sun. This was an early model of the atom suggested by the Danish physicist, Niels Bohr in 1913. He said that electrons are found at certain distances from the nucleus called energy levels. Levels closer to the nucleus correspond to lower energy and those further from the nucleus to higher energy.



electron absorbs incoming photon and jumps up an energy level, photon emitted as electron jumps down an energy level

Open The Hands-on Atom. If you aren't sure what you are supposed to be seeing for any of the following questions, ask your teacher for help.

1) When hit, each bar of the xylophone represents an incoming photon. Which color bar represents

   a) the shortest wavelength? ____________________
   b) the highest frequency? ____________________
   c) the highest energy? ____________________

2) Hit each bar of the xylophone and record what happens when the bar is hit and after you wait a bit. Do all the bars cause something to happen? Explain what you see.

3) Hit the green bar of the xylophone and then the red bar. What happens first? Then what happens? Repeat this several times until you get a end different result after you wait a bit.

4) How do you make an electron jump up to a higher energy level?

5) What happens when an electron jumps down to a lower energy level?

Read Spectral Lines, Bohr's Atom, Energy Levels, and Atomic Spectra (you can also use the "Next" button at the bottom of each of these pages).

6) Why could atomic line spectra be called the "fingerprints" of atoms?

7) How does the Bohr model of the atom explain line spectra?

Activity #5: Bohr's Theory of the Hydrogen Atom

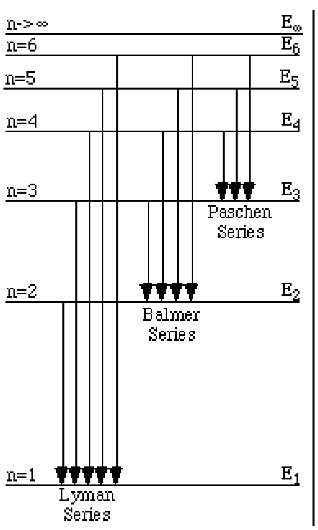
In the Bohr model of a hydrogen atom, the electron travels around the nucleus in a circular orbit. Only a limited number of orbits with certain energies and radii are allowed.

Open Bohr's Theory of the Hydrogen Atom.

1) Choose principal quantum numbers 1-6 from the menu and record the energy of the electron (in eV) for each energy level in the data table.

quantum #	**energy (eV)**
n = 1	
n = 2	
n = 3	
n = 4	
n = 5	
n = 6	

2) Does the energy of an electron increase or decrease as you get farther away from the nucleus?



When an electron falls from one energy level to another, it emits a photon of light whose energy is exactly equal to the difference between the energies of the orbits.

Stars are composed of mostly hydrogen. When studying the spectra of stars, the Balmer lines were among the first studied. Balmer lines are formed when electrons in a hydrogen atom drop down to the 2nd energy level.

You are going to try to recreate the Balmer lines in the simulation Hydrogen Spectroscopy.

3) Using your values from the table in #1, subtract the following energies. Don't forget that the numbers are negative! Using the Spectrum Applet, predict what color will be emitted when the electron makes each of these transitions.

transition	diff. in energy (eV)	color of spectral line
n=6 → n=2	E_6-E_2 =	
n=5 → n=2	E_5-E_2 =	
n=4 → n=2	E_4-E_2 =	
n=3 → n=2	E_3-E_2 =	

Let's see if you are right! Open Hydrogen Spectroscopy.

4) Create an energy level on the energy graph on the right by clicking the "Add Energy Level" button. Move this to the energy value for n=2 (see your table in #1) by clicking the red line (it should turn green when you do this) and dragging the level with the mouse from the left of the vertical scale. Repeat this for n=3, n=4, n=5 and n=6.

5) To create the electron transition from n=6 to n=2, choose energy level 6 on the right side of the vertical scale (it will turn green when your pointer is over it). Click on energy level 6 and drag a transition line to energy level 2. Release the mouse button only when the lower energy level turns green and a spectral line appears in the trial spectrum just below the real spectrum of the gas. Repeat for the other transitions until you have reproduced the Balmer lines. Were your predictions correct? If not, make corrections to your table in #3.

6) Following the same steps as in #4 and #5, recreate the lines from the Lyman and Paschen series. Calculate the energy of one line from each series and show your calculation in the chart below. Using the Spectrum Applet, predict what kind of electromagnetic radiation will be emitted when the electron makes each of these transitions.

Are the Lyman lines to the left (lower energy) or right (higher energy) of the Balmer lines on the hydrogen spectrum?

Are the Paschen lines to the left (lower energy) or right (higher energy) of the Balmer lines on the hydrogen spectrum?

series	diff. in energy (eV) – sample calculation	type of EMR
Lyman		
Balmer	already done in #3	visible
Paschen		

Why do you think the Balmer lines in stars were among the first studied?

THE VISUAL LEARNING PIPELINE