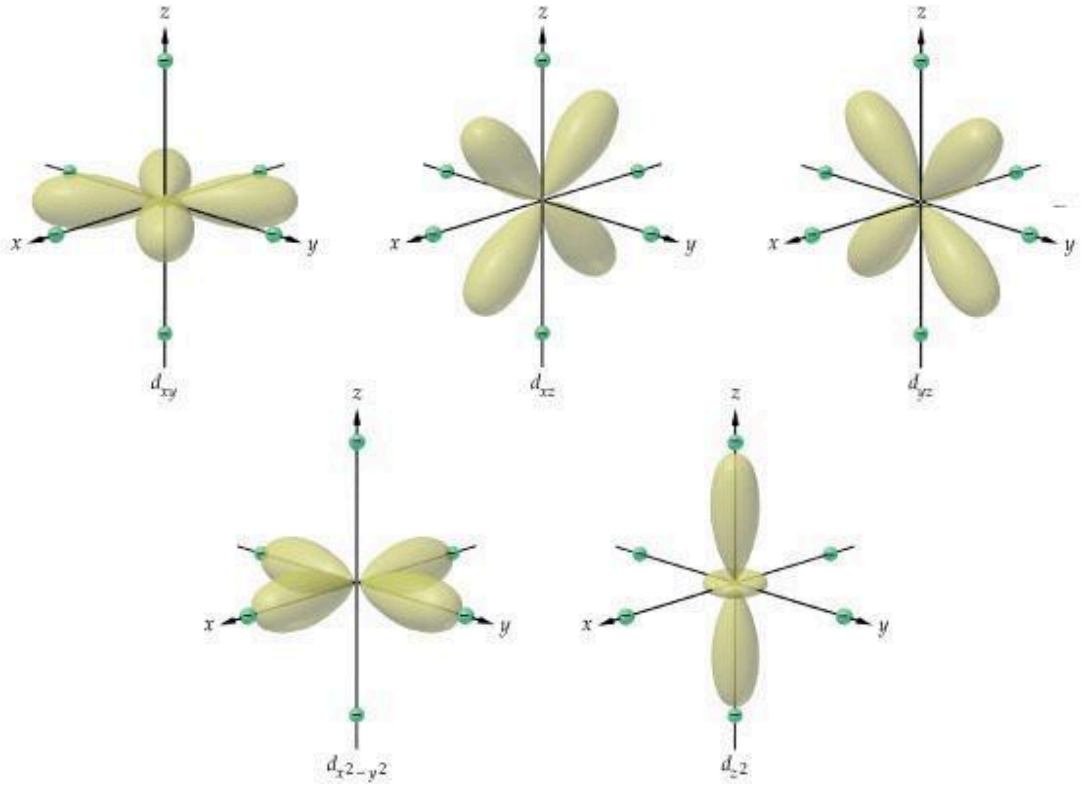
Level 4
Atomic Theory and Periodicity



Level 4 Mission Tracker – Atomic Theory and Periodicity

	Mission	Proof of Clear Understanding "I get it."	Proof of Deeper Understanding "I really get it."
4.1	What is Light?	☐ I watched video 4.1 (12 min) and took notes ☐ Completed WS 4.1 ☐ Completed POGIL Atomic Theory	☐ I can randomly do a problem that Mr. Bergmann prescribes
4.2	The Electromagnetic Spectrum	☐ I watched video 4.2 (10 min) and took notes ☐ Completed WS 4.2	☐ I can randomly do a problem that Mr. Bergmann prescribes AND ☐ Did – Take Home Lab – And then there was Light
4.3	Quantum Theory	☐ I watched video 4.3 (11 min) and took notes ☐ Completed WS 4.3 ☐ Completed Flame Test Lab	☐ I can randomly do a problem that Mr. Bergmann prescribes
4.4 -4. 5	Electron Configurations	☐ I watched video 4.4 (12 min) and video 4.5 (13 min) and took notes ☐ Completed WS 4.4-5	☐ I can randomly do a problem that Mr. Bergmann prescribes

4.6	Periodicity	□ I watched video 4.6 (14 min) and took notes □ Completed WS 4.6	□ I can randomly do a problem that Mr. Bergmann prescribes AND □ Periodicity Graph Activity

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Video 4.1: And then There was Light (12 min)

Pre-Video Question

Why do you think it is harmful for you to look directly at the sun?

Explain in your own words where light comes from. Use the stairstep video to help you explain this.

Draw the energy levels and electrons similar to what your teachers did in the video

What is the difference between red and green light?

How fast does light travel. Explain

Explain how we perceive colors of objects?

Worksheet 4.1 And Then There was Light

1. Explain in your own words how “light” is made.

2. Explain in your own words what your eye sees when you see someone wearing a red shirt.

3. Explain in your own words what your eye sees when you see someone wearing a black shirt.

4. Explain in your own words what your eye sees when you see someone wearing a white shirt.

5. When a television news anchor in a studio speaks to a reporter in a distant country, there is sometimes a noticeable lag between when the anchor speaks in the studio and when the remote reporter hears it and replies. Explain what causes this delay.

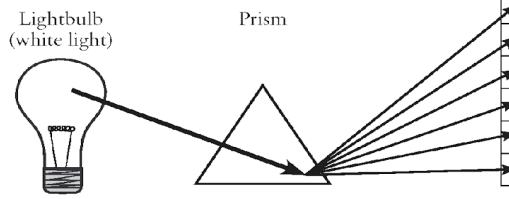
Electron Energy and Light

How does light reveal the behavior of electrons in an atom?

Why?

From fireworks to stars, the color of light is useful in finding out what's in matter. The emission of light by hydrogen and other atoms has played a key role in understanding the electronic structure of atoms. Trace materials, such as evidence from a crime scene, lead in paint or mercury in drinking water, can be identified by heating or burning the materials and examining the color(s) of light given off in the form of bright-line spectra.

Model 1 – White Light



Color	Photon Energy ($\times 10^{-21}$) (J)	Wavelength Range (nm)	Speed (m/s)
Reds	269–318	625–740	3.00×10^8
Oranges	318–337	590–625	3.00×10^8
Yellows	337–352	565–590	3.00×10^8
Greens	352–382	520–565	3.00×10^8
Blues	382–452	440–520	3.00×10^8
Violets	452–523	380–440	3.00×10^8

1. Trace the arrows in Model 1 and shade in the table with colored pencils where appropriate.
2. What happens to white light when it passes through a prism?

3. Why are the color labels in the table in Model 1 plural (*i.e.*, "Reds" rather than "Red")?

4. Do all colors of light travel at the same speed?

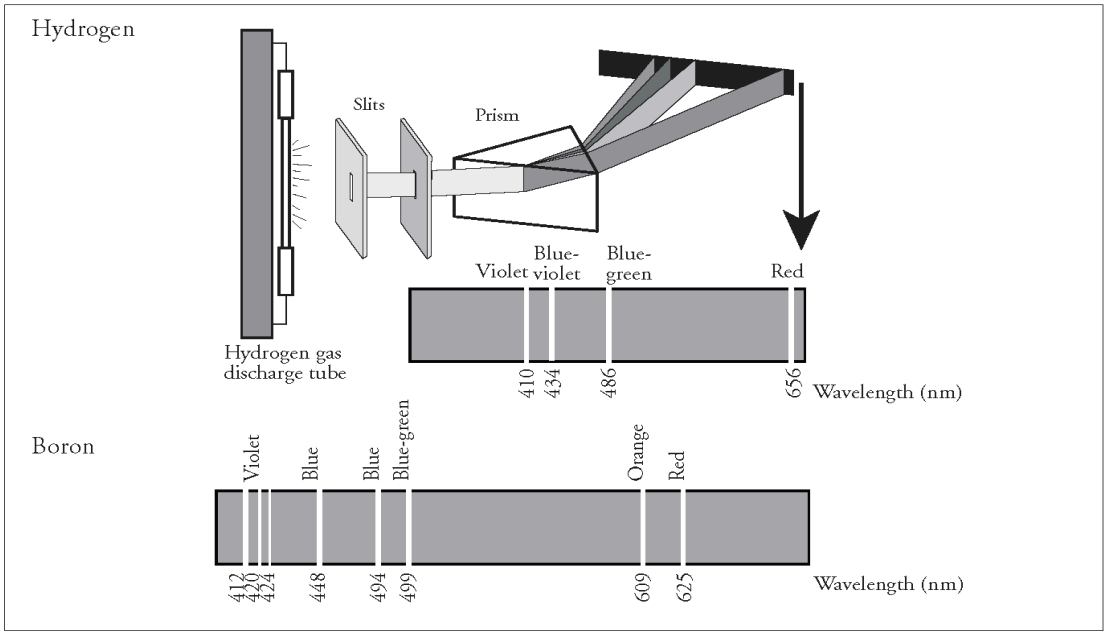
5. Do all colors of light have the same energy? If no, which colors have the highest energy and the least energy, respectively?

6. Consider the light illustrated in Model 1.
   a. Which color corresponds to the longest wavelengths?

   b. Which color corresponds to the shortest wavelengths?

   c. Write a sentence that describes the relationship between wavelength and energy of light.

Model 2 – Emission Spectra for Hydrogen and Boron Atoms



7. Use colored pencils to color the hydrogen and boron spectral lines within their respective spectra in Model 2.
8. List the spectral lines for hydrogen gas by color and corresponding wavelength.

9. The spectral lines for boron were produced using the same method as hydrogen. List three of the colors and corresponding wavelengths for boron's spectral lines as its light passes through a prism.

10. Consider the hydrogen spectrum in Model 2.
    a. Which color of light corresponds to the shortest wavelength?

    b. Which color of light corresponds to the longest wavelength?

11. Consider the hydrogen spectrum in Model 2.

    a. Which color of light has the most energy?

    b. Which color of light has the least energy?

12. Does a gas discharge tube filled with boron emit the same wavelengths of light as a tube filled with hydrogen? Use evidence from Model 2 to support your answer.

13. "The spectral lines for atoms are like fingerprints for humans." How do the spectral lines for hydrogen and boron support this statement?

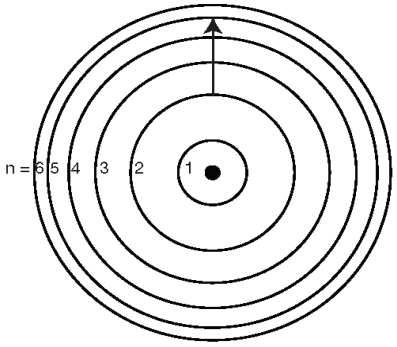
Circle the appropriate word to complete each statement in Questions 14–17.

14. Electrons and protons (attract/repel) each other.
15. As an electron gets closer to the nucleus the (attraction/repulsion) to the nucleus gets (stronger/weaker).
16. For an electron to move from an energy level close to the nucleus to an energy level far from the nucleus it would need to (gain/lose) energy.
17. For an electron to move from an energy level far from the nucleus to an energy level close to the nucleus it would need to (gain/lose) energy.

Read This!

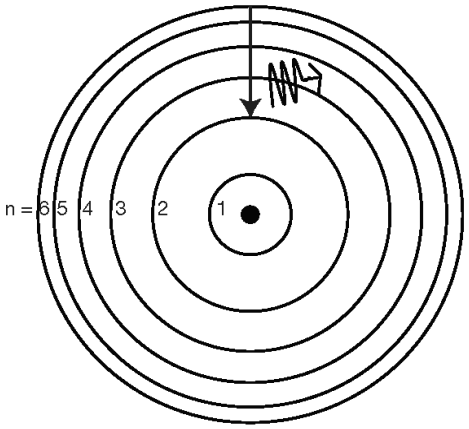
Niels Bohr modified Rutherford's Nuclear Atom model to explain how light interacted with the electrons in an atom to produce spectral lines. His model included electrons orbiting the nucleus at specific energy levels. Electrons absorb energy from various sources (electricity) when they move from lower energy levels (ground state) to higher energy levels (excited states). Energy is released as electrons return to their lower energy levels.

18. Is energy absorbed or released for the electron transition shown in the diagram to the right? Explain.

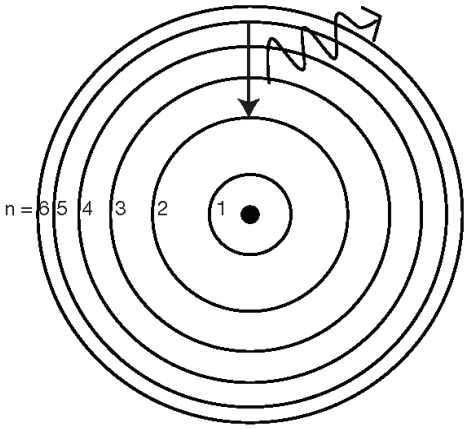


Model 3 – Bohr Model of a Hydrogen Atom

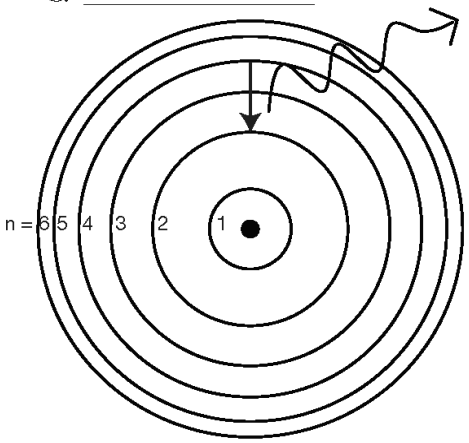
A. _____



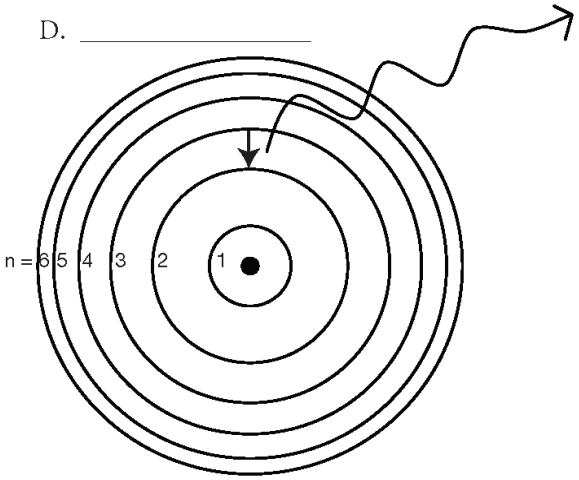
B. _____



C. _____



D. _____



19. Identify the drawing in Model 3 that depicts a hydrogen atom with an electron moving from energy level 5 to energy level 2. Refer to Models 1 and 2 for the following questions.

    a. Label the picture with "n=5 to n=2" and list the corresponding color of light emitted.

    b. This electron transition (absorbs/releases) energy.

    c. This electron moves from a (lower/higher) energy state to a (lower/higher) energy state.

    d. Is light absorbed or released in the electron transition?

20. Label the remaining drawings in Model 3 with the electron transitions that are occurring (n=? to n=?), the wavelengths, and the corresponding colors as given in example A in Model 3. See Model 2 in order to identify the color of spectral lines produced in each of the hydrogen atom electron transitions shown in Model 3. Use colored pencils to trace the light wave in each of th four pictures with the appropriate color.

21. Consider the electron transitions in Model 3.

    a. Which of the electron transitions involves the most energy?

    b. Explain why this transition involves the most energy based on your understanding of the attractive forces between the electrons and protons in the atom.

22. Explain why a single atom of hydrogen cannot produce all four hydrogen spectral lines simultaneously.

23. If Question 22 is true, how can we see all four colors from a hydrogen gas discharge tube simultaneously?

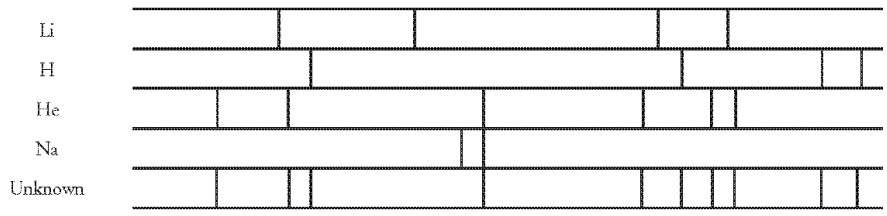
Extension Questions

24. The hydrogen spectral lines in Model 2 are only the wavelengths of light that are in the visible range and therefore "seen" by the naked eye. However, many other wavelengths can be detected with special equipment.

    a. Propose a hydrogen electron transition that involves light with a wavelength in the ultraviolet (UV) range (10–400 nm).

    b. Propose a hydrogen electron transition that involves light with a wavelength in the infrared (IR) range (1000–106 nm).

25. Below are diagrams for the bright line spectra of four elements and the spectrum of a mixture of unknown gases.



    a. Which element(s) are not present in the Unknown?

    b. Which element(s) are in the Unknown?

26. Model 2 shows the emission spectra for hydrogen and boron. Scientists can also record the absorption spectra for elements. Propose how this might be done, and what the absorption spectra of hydrogen and boron would look like.

Video 4.2 Electromagnetic Radiation (10 min)

Pre-Video Question

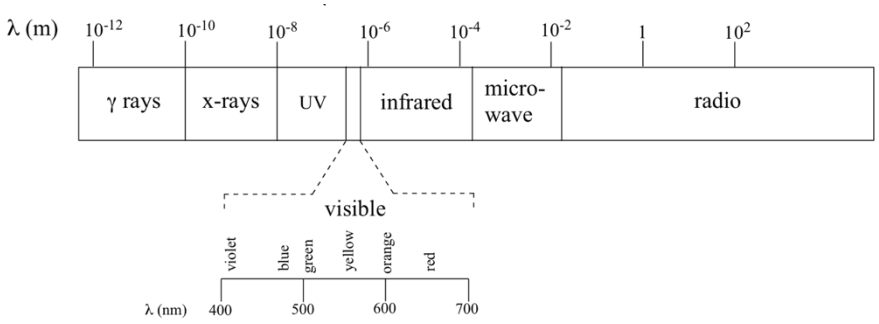
Why do you think X-Ray Technician puts a lead-lined apron on you whenever you have an X-Ray?

What is Electromagnetic Radiation?

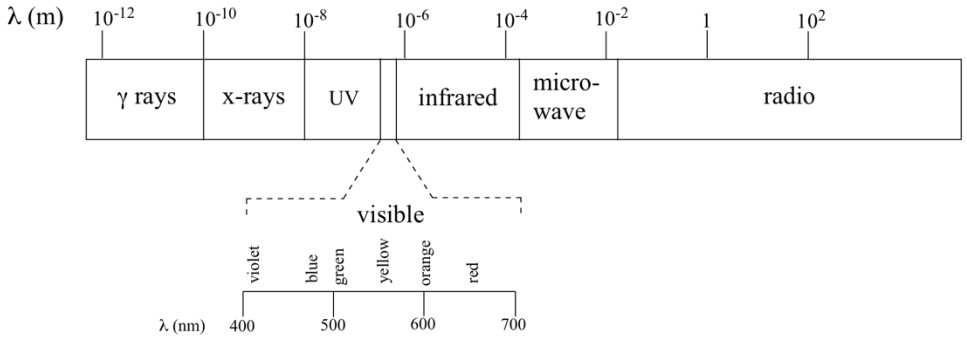
What is the difference between visible light and the rest of the electromagnetic spectrum?

Sketch the waves that were done in the video.

Label the diagram below as was done in the video. Make sure to indicate wavelength, frequency, and energy.



Worksheet 4.2 The Electromagnetic Spectrum



1. The light produced by a red neon sign is due to the emission of light by excited neon atoms. Qualitatively describe the spectrum produced by passing light from a neon lamp through a prism.

2. Sketch two waves, one with a high energy and one with low energy

3. How fast does light travel?

4. Rank the following types of electromagnetic radiation from lowest to highest Energy
   a. UV
   b. Microwave
   c. Red light
   d. Orange light
   e. Radio Waves
   f. X-rays

5. Rank the following types of electromagnetic radiation from lowest to highest wavelength
    a. UV
    b. Microwave
    c. Red light
    d. Orange light
    e. Radio Waves
    f. X-rays

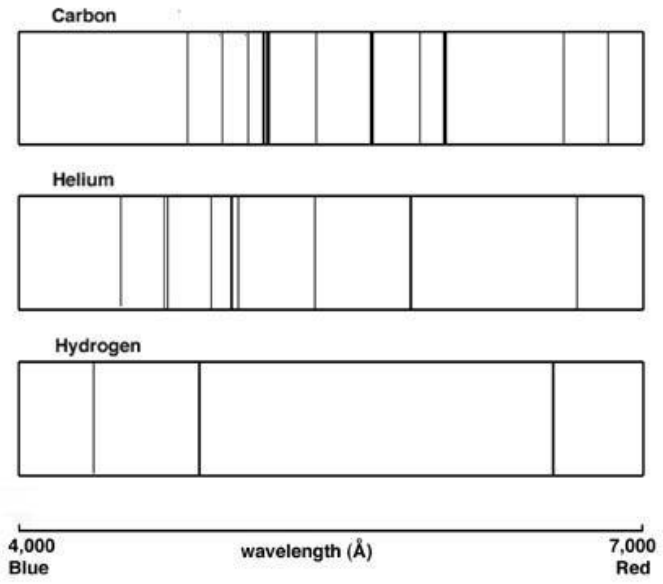
6. You might think that microwave radiation would be harmful to humans because you know that putting food into a microwave oven heats it up. However, microwave radiation is all around us and is, in fact, used for cell phone communication. Explain how low energy microwaves heat up food in a microwave oven.

7. Give an example of energy carried by an electromagnetic wave.

8. Part of the light passing through the air is scattered in all directions by the molecules comprising the atmosphere. The wavelengths of visible light are larger than molecular sizes, and the scattering is strongest for wavelengths of light closest to sizes of molecules.
   (a) Which of the main colors of light is scattered the most? (b) Explain why this would give the sky its familiar background color at midday.

9. What property of light corresponds to loudness in sound?

10. The diagram below represents the spectra of three different elements. Explain the following: Why are they different



11. Why are they not a continuous series of colors (ROYGBIV)?

12. How are these used in the field of Astronomy?

Video 4.3 A Fuller Picture of the Atom (12 min)

Pre-Video Question

Skim the Wikipedia page for the 1990's show "Quantum Leap." Why is the word quantum used in the title of this show?

Summarize what you learned from the video about hydrogen gas.

Sketch the orbital diagram of hydrogen and indicate the total number of colors that could come from an atom if the Bohr model is correct.

Summarize the double slit experiment (the cartoon) and what it tells us about the atom.

Explain your understanding of quantum…

Flame Test Lab

Chemists began studying colored flames in the 18th century and soon used "flame tests" to distinguish between some elements. Different elements burn with different colored flames. Although some of the flames you will be seeing will appear similar in color, their light can be resolved (separated) with a prism into distinctly different bands of colors on the electromagnetic spectrum (ROYGBIV). These bands of colors are called **atomic line spectra**, and they are UNIQUE to each element. Niels Bohr studied the line spectrum for hydrogen, and wondered what the specific line spectrum had to do with the structure of the atom. He postulated that an electron can have only specific energy values in an atom, which are called **energy levels**. Bohr believed that the energy levels for electrons were **quantized**, meaning that only certain, specific energy levels were possible. How does an electron move between energy levels? By gaining the right amount of energy, an electron can move, or undergo a transition, from one energy level to the next. We can explain the emission of the light by atoms to give the line spectrum like this:

1. An electron in a high energy level (excited state) undergoes a transition to a low energy level (ground state).
2. In this process, the electron loses energy, which is emitted as a photon (a particle which behaves like a wave)
3. The energy difference between the high energy level and the low energy level is related to the frequency (color) of the emitted light.

Pre-lab questions:

1. Bohr's important discovery was that energy levels of electrons are quantized (only existing in certain, specific levels). In what year was this discovery made?

_____

2. What happens to an electron when energy is added?

3. What is released when an electron loses energy?

4. What determines the frequency (color) of photons?

5. Why do you think the frequencies (color) for a specific element is always the same?

Procedure: In this lab, you will be observing the colors of the flames for 7 different elements: **lithium, sodium, potassium, calcium, strontium, barium,** and **copper.** Each element is dissolved in a solution of its chloride salt. There is a different solution at each lab station. You will go around to all 7, perform the flame test, and make **CAREFUL** observations of the colors. You will then be given an unknown solution, for which you will have to use your notes below to determine which unknown you were given.

Data Table:

Li	Na	K
Ca	Sr	Ba
Cu	unknown # ____	unknown # ____

Based on your observations, what are the identities of your 2 unknowns?

Unknown # _____ is _____ **Unknown # _____ is _____**

Post- Lab Questions:

1. If you had 2 colors that seemed identical, how could you tell them apart more accurately?

2. On the far ends of the visible spectrum of light, there exists ultraviolet (**UV**) radiation and infrared (**IR**) radiation.

- **UV radiation is dangerous.** UV radiation is located just past violet on the spectrum.

- **IR radiation is harmless.** It is located just past red on the spectrum.
- Based on what you calculated in parts a & b, explain -why- UV is more dangerous than IR:

Take Home Lab And then There was Light

Parent/Student Experiment

Subject/Concept: Chemistry - Photon Emission

Purpose:
The purpose of this activity is to observe the emission of photons in your own home! Don't worry, this happens all the time!

Materials:
several commercial bandage strips (3" x .75" with pull-apart packaging - no strings!)
CURAD™, HEB, OR SAFEWAY™ brands work well
regular Wintergreen LifeSavers™ candies or Wintergreen LifeSavers™ Holes

Procedure:
In an absolutely pitch dark room (bathrooms often work), do the following:
Pull apart the bandage strip packaging with very quick pulls of about a half inch or so. You should see the emission of a small purple photon!
While your partner looks on, crush the wintergreen candy between your teeth and your partner will see the emission of a small photon!

Questions:

1. What is the source of the emitted photon?

2. Make a drawing of the Rutherford-Bohr model of an atom showing the movement of an electron during the process of light emission.

For Credit:

To receive credit, complete the questions and have, your parent or guardian either write a short note or shoot a short video confirming that you performed the experiment for them and explained the results to their satisfaction using the concept of photon emission and electron energy levels.

Worksheet 4.3: A Fuller Picture of the atom

1. Explain why there are just distinct spectral lines when we look at the spectra of individual atoms.

2. Briefly explain what is meant by "wave-particle duality of light" in your own words.

3. How would doubling the frequency of a given photon affect the amount of energy associated with an electron?

4. How would doubling the wavelength of a given photon affect the amount of energy associated with an electron?

5. How are the Bohr model and the quantum mechanical model of the hydrogen atom similar? How are they different?

6. What does it mean to say that the energy of the electrons in an atom is quantized?

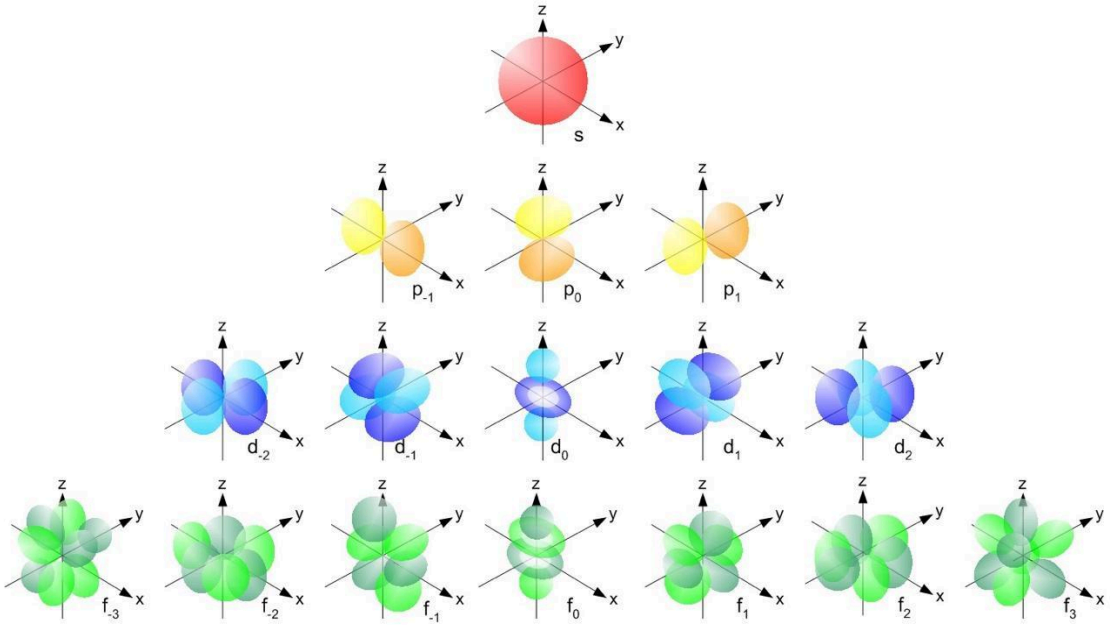
Video 4.4: Electron Configurations Part 1 (12 min)

Pre-Video Question

Since all electrons have a negative charge, what do you think happens when they get close to each other?

List the four different kind of sub levels found in an atom.

Next to each type of orbital below label the number of orbitals and the maximum number of electrons that can fit in each orbital.



Copy down the chart from the video (with the diagonal lines)

Write out the electron orbital (box) and electron configuration of Helium

Write out the electron orbital (box) and electron configuration of Nitrogen

What is “Hunds Rule?”

Write out the electron orbital (box) and electron configuration of Bromine

Video 4.5 Electron Configs Part 2 (13 min)

Pre-Video Question

Why do you think electrons like to occupy the lowest energy levels first?

Make sure you get out your periodic table and mark it up as you watch the video

Mark up the periodic table and add the orbitals blocks, The s, p, d, f

Complete this statement

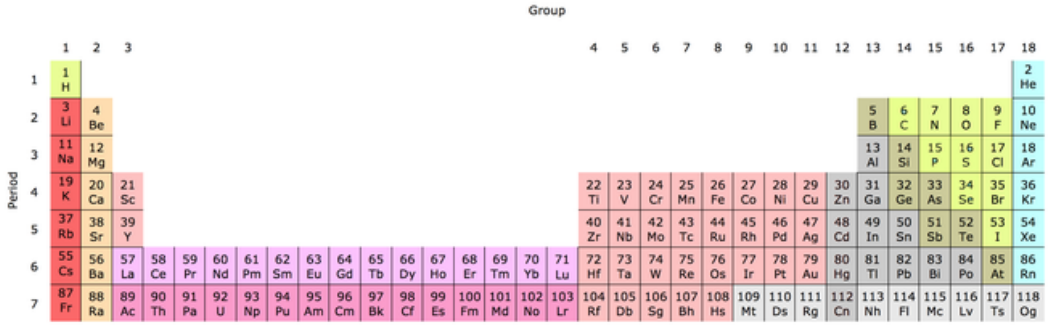
You read the periodic table like a _____. Left to _____, top to _____

Write down the order of the filling of electron orbitals that Mr. Bergmann illustrates in the video.

$1s^2$, $2s^2$,

_____

Comment on why the actual periodic table shape is what you see below



Copy down the electron configuration of Iron, Fe as done in the video

Copy down the electron configuration of Bromine, Br as done in the video

Explain the shorthand notation

Worksheet 4.4-4.5 Electron Configurations

For each of the elements listed below, complete the following:

a. long hand electron configuration

b. orbital diagram (boxes with arrows)

c. short hand electron configuration (begins with a noble gas)

1. **Li**

2. **Na**

3. **K**

4. **B**

5. **Al**

6. **Ne**

7. **Ar**

8. **Mg**

9. **P**

10. **Ni**

11. **Zn**

12. **Br**

13. **H**

14. **He**

15. **Ca^{2+}**

16. **N^{3-}**

17. **Na^{1+}**

Video 4.6: Periodicity (14 min)

Pre-Video Questions

Look up the word periodic. What does it mean?

What is periodicity in relation to the Periodic Table?

Sketch how scientists can determine the **size** of an atom

What is the trend of atomic radii on the periodic table? (Sketch and indicate which atoms have the highest and lowest atomic radii)

Explain how cations and anions change size compared to the atom from whence they came.

Sketch the size of the atoms and ions that were presented in the video.

What is Ionization Energy

How is ionization like a shepherd and her flock of sheep?

What is the periodic trend of first ionization energy of the Periodic table? (Sketch and indicate which atoms have the highest and lowest first ionization energy)

What is electronegativity?

What is the periodic trend of electronegativity of the Periodic table? (Sketch and indicate which atoms have the highest and lowest electronegativity)

What questions do you have from the video?

Worksheet 4.6 Periodicity

1. List the following atoms in order of increasing electronegativity:
    a. Cr, Ni, Ga, K

    b. P, As, F, Hg, Fr

2. List the following atoms in order of increasing atomic radius:
    a. Cr, Ni, Kr, Ga, K

    b. P, As, F, Hg, Fr

3. List the following atoms in order of increasing ionization energy:
    a. Cr, Ni, Kr, Ga, K

    b. P, As, F, Hg, Fr

4. Why are alkali metals stored in kerosene or mineral oil? Why are they not allowed to sit out in the air?

5. The Mg^{+2}, and the Na^{+1} ions each have ten electrons surrounding the nucleus. Which ion would you expect to have the smaller radius?

Periodic Trends

Can the properties of an element be predicted using a periodic table?

Why?

The periodic table is often considered to be the "best friend" of chemists and chemistry students alike. It includes information about atomic masses and element symbols, but it can also be used to make predictions about atomic size, electronegativity, ionization energies, bonding, solubility, and reactivity. In this activity you will look at a few periodic trends that can help you make those predictions. Like most trends, they are not perfect, but useful just the same.

1. Consider the data in Model 1 on the following page.
   a. Each element has three numbers listed under it. Which value represents the atomic radius?

   b. What are the units for the atomic radius?

   c. Write a complete sentence to convey your understanding of atomic radius. *Note:* You many not use the word "radius" in your definition.

2. In general, what is the trend in atomic radius as you go down a group in Model 1? Support your answer, using examples from three groups.

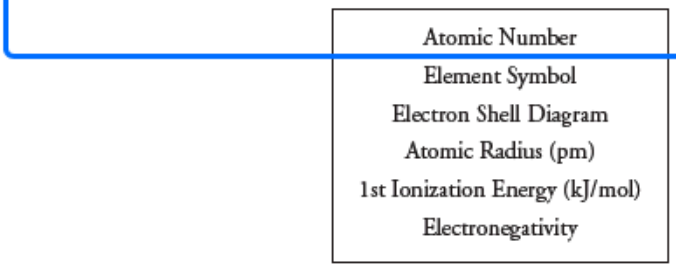
3. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in atomic radius that you identified in Question 2. *Hint:* You should discuss either a change in distance between the nucleus and outer shell of electrons or a change in the number of protons in the nucleus.

4. In general, what is the trend in atomic radius as you go across a period (left to right) in Model 1? Support your answer, using examples from two periods.

5. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in atomic radius that you identified in Question 4.

Model 1 – Main Group Elements

1 H							2 He
37							31
1312							2372
2.1							N/A
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
152	112	83	77	71	66	71	70
520	900	801	1086	1402	1314	1681	2081
1.0	1.5	2.0	2.5	3.0	3.5	4.0	N/A
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
186	160	143	117	115	104	99	98
496	738	578	786	1011	1000	1251	1521
0.9	1.2	1.5	1.8	2.1	2.5	3.0	N/A
19 K	20 Ca	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
227	197	122	123	125	117	114	112
404	550	558	709	834	869	1008	1170
0.8	1.0	1.7	1.8	1.9	2.1	2.5	N/A



Note: The transition elements and f-block elements have been removed from the periodic table here to ease the analysis of the trends.

6. Locate the numbers in Model 1 that represent the ionization energy. The **ionization energy** is the amount of energy needed to remove an electron from an atom.

   a. Using your knowledge of Coulombic attraction, explain why ionization—removing an electron from an atom—takes energy.

   b. Which takes more energy, removing an electron from an atom where the nucleus has a tight hold on its electrons, or a weak hold on its electrons? Explain.

7. In general, what is the trend in ionization energy as you go down a group? Support your answer using examples from three groups.

8. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in ionization energy that you identified in Question 7.

9. In general, what is the trend in ionization energy as you go across a period? Support your answer using examples from two periods.

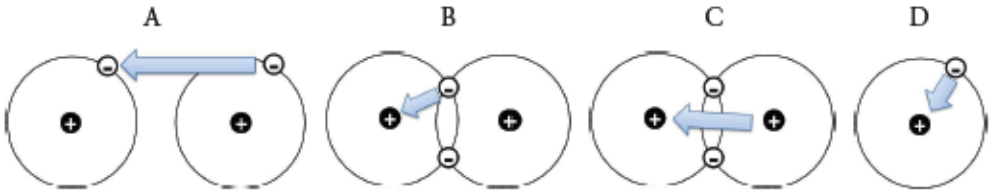
10. Using your knowledge of Coulombic attraction and the structure of the atom, explain the trend in ionization energy that you identified in Question 9.

11. Atoms with loosely held electrons are usually classified as metals. They will exhibit high conductivity, ductility, and malleability because of their atomic structure. Would you expect metals to have high ionization energies or low ionization energies? Explain your answer in one to two complete sentences.

Read This!

Electronegativity is a measure of the ability of an atom's nucleus to attract electrons from a different atom within a covalent bond. A higher electronegativity value correlates to a stronger pull on the electrons in a bond. This value is only theoretical. It cannot be directly measured in the lab.

12. Using the definition stated in the *Read This!* box above, select the best visual representation for electronegativity. Explain your reasoning.



13. Locate the electronegativity values in Model 1.

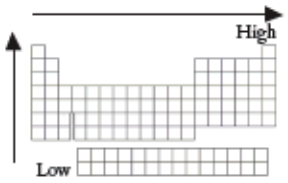
    a. What is the trend in electronegativity going down a group in Model 1?

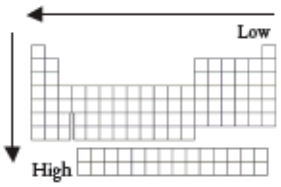
    b. Explain the existence of the trend described in part *a* in terms of atomic structure and Coulombic attraction.

    c. What is the trend in electronegativity going across a period in Model 1?

    d. Explain the existence of the trend described in part *c* in terms of atomic structure and Coulombic attraction.

14. The two diagrams below can summarize each of the three trends discussed in this activity. Write "atomic radius," "ionization energy," and "electronegativity" under the appropriate diagram.





Extension Questions

15. During this activity you may have noticed that not all of the data provided in the models followed the trends.

    a. Identify two places in Model 1 where the property listed does not fit the trend identified in this activity.

    b. Why is it still beneficial for chemists to understand as many periodic trends as they can?

    c. Propose an explanation for one of the exceptions you identified in part *a*. Use your knowledge of atomic structure and Coulombic attraction in your hypothesis.

16. Rank the following elements from **smallest to largest** electronegativity based on the trends you have discovered thus far in the periodic table: barium (atomic number 56), bromine (atomic number 35), and iron (atomic number 26). Explain your reasoning.