Course and Section_______ Names ___________________________

Date___________________ ___________________________

ATOMIC PHYSICS SIMULATION

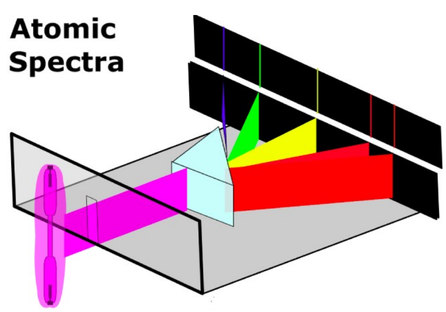
Introduction

In this simulation you will explore the atomic spectra produced by a gas and the energies associated with the spectra lines as described in the Bohr model of an atom.

Submit your answers using Blackboard.

When gases are placed in a tube and subjected to a high-voltage electric discharge, the electrons in the atoms can be excited to higher energy levels within the atoms; when they return to their original levels electromagnetic radiation is emitted. Some of this radiation may be in a wavelength region that is visible to the human eye.

Open this simulation (https://www.showmethephysics.com/home/animations3/modernPhysics/atomic_spectra5.htm)



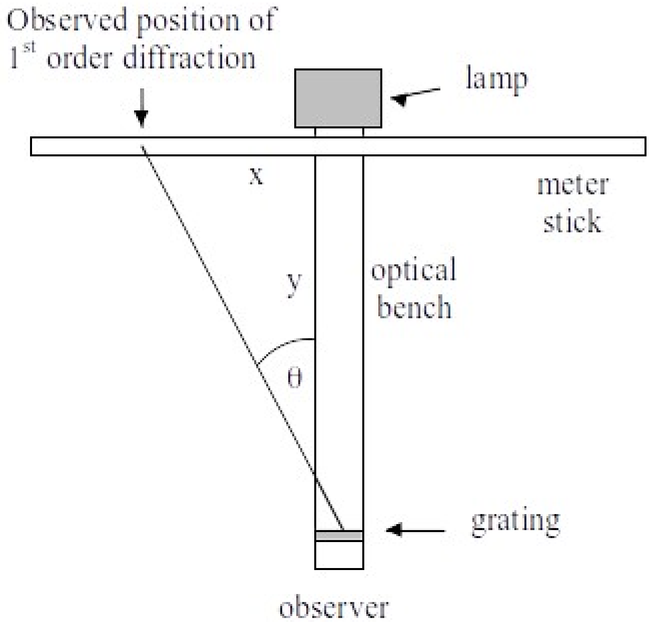
On the left there is a lamp containing He gas. The light emitted from the lamp passes through a prism which disperses the wavelengths at different locations on a screen. The spectra lines are the lines you see on the screen.

Spectra lines can also be generated in a different way as shown in the figure on the next page. You are the observer at the bottom and light is emitted toward you from the lamp located at the top. A diffraction grating is used instead of the prism and the spectral lines appear as if they were on a screen just in front of the lamp.

Submit your answers using Blackboard.

1 – Find the Grating

Your goal is to determine *d* the grating spacing using a given set of data.



The relationship between the wavelength, the grating spacing and the diffraction angle is

$$m\lambda = d\sin(\theta)$$

where *m* is the order of diffraction (for this experiment you can only see the first order, so *m* = 1).

Suppose the gas contained in the lamp is Hg (mercury): in this case you can observe three spectra lines : Yellow line (λ = 571nm), Green line (λ = 546 nm), Violet line (λ = 436 nm). You work with one color at the time where the location of a spectral line is given by the *x* value measured. The optical bench has length *y* = 100 cm.

Yellow Line *x* = 38.2 cm
1 Calculate the sin θ (use trigonometry and the *x*,*y* values)
2. By knowing the wavelength of yellow find *d.* (mm/line)

Green Line *x* = 36.5 cm
3. Calculate the sin θ (use trigonometry and the *x*,*y* values)
4. By knowing the wavelength of green find *d.* (mm/line)

Violet Line *x* = 29.2 cm
5. Calculate the sin θ (use trigonometry and the *x*,*y* values)
6. By knowing the wavelength of violet find *d.* (mm/line)
You might have obtained slightly different values of *d.*
7. Calculate the average value of *d.* (mm/line)
8. Calculate how many lines/mm there are in the diffraction grating *N=1/d.* (be careful with the units).

2 – Find the Wavelengths

Now that you know *d* you will do the reverse process and your goal is to find the wavelengths corresponding the spectra lines located at different *x*. Once you know the wavelengths you can use that info to identify the new gas inside the lamp.

First Line x = 43.9 cm
9. Calculate the sin θ (use trigonometry and the *x*,*y* values)
10. By knowing *d* find the first wavelength. (nm)

Second Line x = 32.6 cm
11. Calculate the sin θ (trigonometry and the *x*,*y* values)
12. By knowing *d* find the second wavelength. (nm)

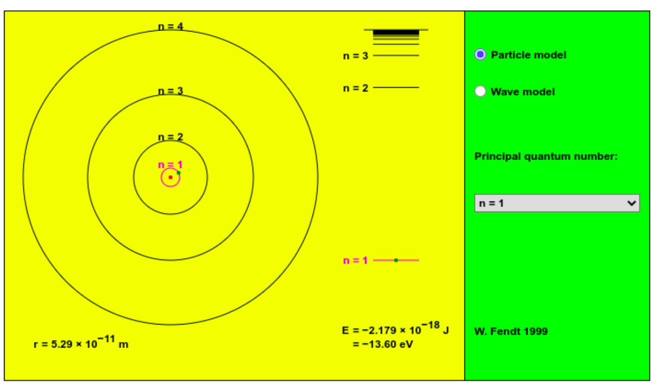
Third Line x = 29.1 cm
13. Calculate the sin θ (trigonometry and the *x*,*y* values)
14. By knowing *d* find the third wavelength. (nm)

15. What is the mystery gas inside the lamp? (Do some search online/textbook)

3 – Energy Level

A hydrogen atom consists of a proton and an electron. The Bohr model of the hydrogen atom states that the electron surrounding the proton cannot be found at any radii. Only a discrete or quantized set of radii are allowed. This in turn implies only a quantized set of energy levels of the electron are allowed. Despite the fact that the reality of the situation is much more complicated Bohr's model was an important step towards a precise theory of atomic structure.

Open the simulation (https://www.walter-fendt.de/html5/phen/bohrmodel_en.htm)



The applet displays a set of radii allowed by the Bohr model. In addition it also displays the quantum number associated with that radii and the energy of the system.
16. What is the energy difference between the n = 1 and n = 2 levels of the electron? (eV)
17. Is there an energy level n = 1.5? (Try clicking on the orbit and dragging it to the " n = 1.5" level)

For an electron to move from a lower energy level to a higher energy level it must absorb a photon with the corresponding amount of energy.

18. What energy in eV of a photon is necessary for the electron to “jump” from the $n = 2$ to $n = 5$ state? (eV)

When an electron is in a higher energy state it may spontaneously emit a photon and return to its lower energy state. These photons carry an energy equal to the energy difference between the levels.

19. If an electron is in the $n = 4$ state which states can it “fall down” to by emitting a photon?

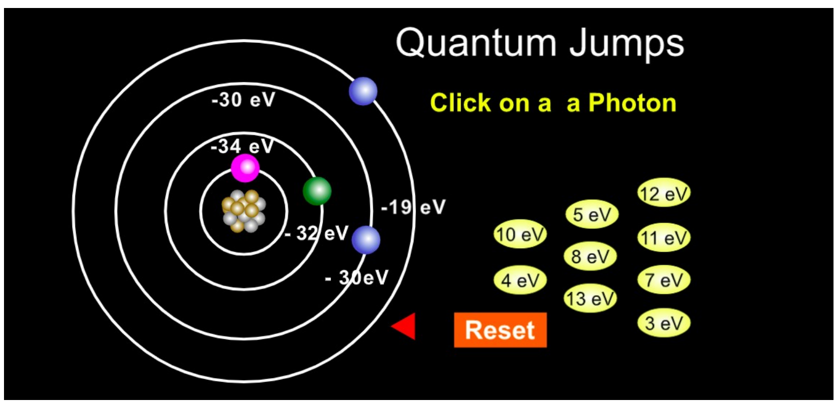
20. What are the photon energies that correspond to the above transitions? (eV)

For a photon $E = hc/\lambda$ where $h = 4.1357 \times 10^{-15}$ eVs is the Planck’s constant, $c = 3.0 \times 10^{8}$ m/s is the speed of light and λ is the wavelength.

21. What is the wavelength of the photons found in question 19? (nm)

Open the simulation and chick play (the red triangle) (https://www.showmethephysics.com/home/animations3/modernPhysics/bohr_transitions5.htm)

If you have difficulty playing the simulation it helps to have the window be full screen. On some systems you need to click just to the right of the play button.



The simulation shows a “toy” atom (the numerical values of the energies are not realistic) and four energy levels -34 eV, -32 eV, -30 eV, -19 eV. The numbers in the yellow bubbles correspond to photons with the labeled energy. If you click on a photon it will be sent in to the atom. Send a few of them.

22. Are there any photons which pass through without being absorbed?

Recall that only photons whose energy corresponds to the energy difference between orbitals will be absorbed, and excite an electron to a higher energy level. Find which photons are absorbed, input your answers in order of increasing energy

23. Find which photons are absorbed and the corresponding energy levels

Photon energy eV	Energy level (lower) eV	Energy level (higher) eV

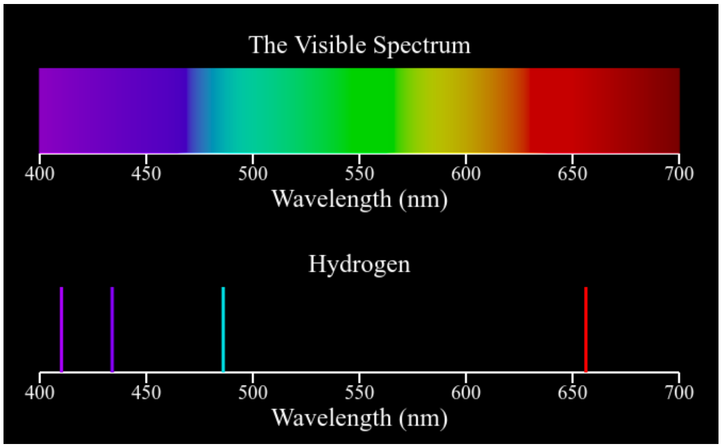
4 – Rydberg's Equation

If we consider the Bohr model the electrons only exist in a stable configuration at a discrete set of radii. When electrons move from a higher to lower discrete (quantized) radii they emit photon's of energy equal to the energy gap between the two radii. Rydberg's equation can be used to calculate the wavelength of the resulting photon,

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

where $R_H = 1.096 \times 10^7 m^{-1}$ is the Rydberg constant, n_1 and n_2 are the quantum numbers which label the energy levels associated with the transition and λ is the wavelength of the emitted photon. In this formula $n_2 > n_1$ i.e. n_2 is the initial quantum number and n_1 is the final quantum number. Remember, photons are emitted as the electron "falls down" from a higher quantum number state to a lower quantum number state.

Open the simulation (http://physics.bu.edu/~duffy/HTML5/emission_spectra.html)



Click on *Hydrogen*. The applet displays the atomic spectrum of electronic transitions in hydrogen. In particular it displays the transitions in the visible light. This corresponds to whats known as the Balmer series which is the Rydberg equation with n_1 =2. Your goal is to use the Rydberg equation and figure out which quantum transition corresponds to which color (i.e. find n_2)

24. The red line is at 656.3 nm. This corresponds to a transition to $n_1 = 2$ from $n_2 = ?$
25. The turquoise line is at 486.1 nm. This corresponds to a transition to $n_1 = 2$ from $n_2 = ?$
26. The blue/purple line is at 434.0 nm. This corresponds to a transition to $n_1=2$ from $n_2 = ?$
27. The violet line is at 410.2 nm. This corresponds to a transition to $n_1=2$ from $n_2 = ?$