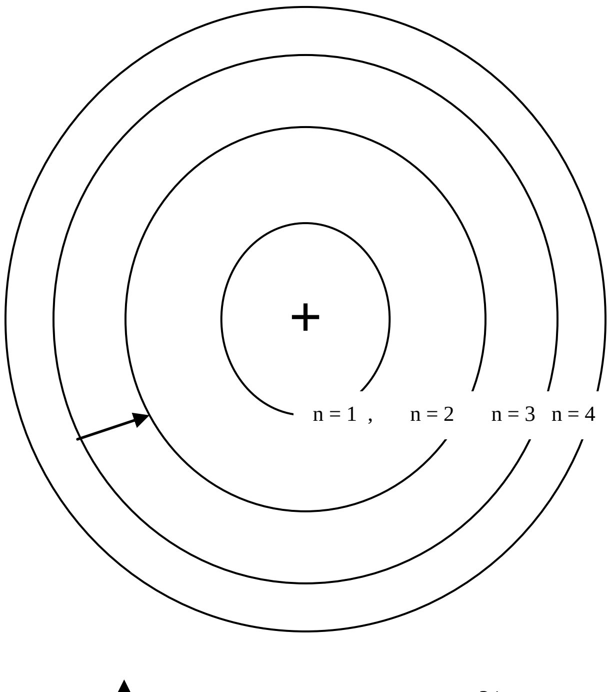
EXPERIMENT 21.

Name: ____________________
Section __________

Part 1. Bohr's Planetary Model



The "Planetary" model of the atom has electrons "orbiting" around the nucleus in specific "orbits" or *Energy levels.* If an electron undergoes a *transition* from a high to a lower level, light is emitted with energy equal to the difference in the energies of the two energy levels .
The transition is represented as an arrow.The energy of the emitted light is inversely proportional to its wavelength (λ) or directly proportional to its frequency (ν) .

$$E = h\nu = hc / \lambda$$

$\lambda \times \nu = c$ (**c** = 3.00×10^8 m/sec) (**h** is Planck's constant = 6.63×10^{-34} J sec ν has the unit sec^{-1}, also called "Hertz" or Hz , while λ in this equation is given in meters. λ by itself is usually expressed in nm (10^{-9}m) or Å (Ångström = 10^{-10} m) .

Exercises: use extra paper as necessary

1. Orange light emitted from glowing mercury vapor has a frequency of about 4.80×10^{14} sec^{-1} . Calculate the wavelength of this light in m , nm , and Å .

2. The energy of light (and any other electromagnetic energy) is given by Planck's equation: E = hν or hc/λ Calculate the energy in Joules, of the yellow light in problem 1 .

3. Light can be characterized as a collection of particles called "***photons***" . The calculation in problem 2 gives the energy of one photon of yellow light. Calculate the energy of a mole of photons (use Avogadro's #), and express the answer in kJ / mole .

In the lab: Your instructor will demonstrate, or you will follow a simple procedure to illustrate how light is emitted from atoms with electrons in higher energy level

a) Simple flame tests involve imparting energy to atoms, and allowing the energy to come back out as light of various colors.
Describe the various colors of light emitted from solutions of the following ions when exposed to a flame.

Na^+ __________________ K^+ ______________________ Ca^{2+}________________

Li^+ __________________ Sr^{2+} _____________________ Ba^{2+} _______________

b) Examine light emitted from helium and hydrogen in spectroscopes.
A spectroscope takes light from a glowing gas and separates it into specific colors with characteristic wavelengths.

When white light is passed through a prism or diffraction grating, one can separate violet light (λ = 400-420 nm), blue (~ 440-460 nm), green (460-500 nm), yellow (500 – 600 nm), orange (600 – 650nm) and red (up to 700 nm) light.

The prism or diffraction grating in the spectroscope projects the specific colors onto a scale. The scale in the spectroscopes is given in cm x 10^{-5} Since 1 cm = 10^7nm , a scale reading on our spectroscopes of 1 is equivalent to 100 nm; a scale reading of 4 is equivalent to 400 nm. Record the **wavelengths** and **colors** of the lines coming from the glowing hydrogen gas and the glowing helium gas . (Convert the scale to nm)

	color	λ			color	λ	
H	______________	____________	nm	He	_______________	____________	nm
	______________	____________			_______________	____________	
	______________	____________			_______________	____________	
	______________	____________			_______________	____________	
					_______________	____________	
					_______________	____________	

note – you may not see all 4 lines
- the one close to 400 nm is dim

Niels Bohr was able to calculate the wavelengths of the light emitted by glowing hydrogen gas, for transitions between higher energy levels (n = 3,4, etc) and the second energy level (n = 2).
The formula is:

$$\lambda = \frac{91.2 \text{ nm}}{0.250 - 1/n^2}$$

where n = 3 or 4 or 5 or 6

calculated values
____________ nm
____________ nm
____________ nm
____________ nm

Calculate λ (n = 3,4,5, 6) , to obtain 4 wavelengths.
:Compare these with the wavelengths of the light you saw in the spectroscope

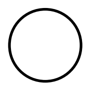
Part 2. The Quantum Mechanical Model

This model of the atom, has the electrons behaving as waves, and only certain waves are mathematically possible in a closed 3-D system such as the atom, which give rise to a description of probability of finding the electrons in certain regions of the atoms. These probability distributions give rise to 3-D pictures called "***orbitals***" . The number and types of orbitals vary with the energy levels and sublevels (subshells) in the atom.

Thus the **principal energy levels** (designated n = 1 or 2 etc) split into **sublevels (or "subshells)** of different energies, which further split into **orbitals** .

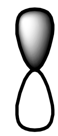
The first energy level remains unsplit – and contains a spherical-shaped "**s**" orbital .
(1 s subshell has 1 orbital) The 2^{nd} (n = 2) level is split into two subshells, the 2s (one orbital) and the 2p (three orbitals).

s orbitals are spherical



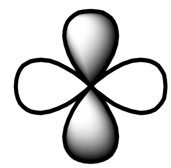
s

the three p orbitals have dumbell shapes and are oriented along an x,y,z axis



p

The 3^{rd} energy level has
A 3 s subshell (1 orb) , a 3 p subshell (three orbs) and a 3 d subshell of five orbitals having cloverleaf shapes.



d

The 4^{th} energy level is split into 4 subshells : 4s (one orb) 4 p (three orbs) 4d (five orbs) and 4 f (five orbs)

The 4f orbitals have complex shapes and there is no need to learn how to sketch them. The energies of all the orbitals are plotted, in what is called an **"Aufbau"** diagram :

_____ ____ _____ 7p ……………………. 118 [?] - as yet undiscovered noble gas.
____ ____ ____ ____ 6d
____6d ___ ___ ___ ___ ___ ___ ___ 5f …….actinides
_____ 7s

Each noble gas configuration has a filled outer p subshell

____ _____ _____ 6p ……………………..86 …[Rn]
____ ____ ____ ____5d
____ 5d ___ ___ ___ ___ ___ ___ ___ 4f …… lanthanides
_____ 6s

one e^- goes into the 5d before the 4f subshell , then after the 4f is filled, the electrons fill the 5d subshell

_____ _____ _____ 5p ……………. 54 …… [Xe]
____ ____ ____ ____ ____ 4d
_____ 5s

_____ _____ _____ 4p ……………… 36 …. [Kr] #37 Rb = [Kr] $5s^1$
____ ____ ____ ____ ____ 3d
_____ 4s

_____ _____ _____ 3p ……………. 18 ….. [Ar] #19 K = [Ar] $4s^1$
_____ 3s

_____ _____ _____ 2p ……………. 10 …..[Ne] #11 Na = [Ne] $3s^1$
_____ 2s

••
_____ 1s …………………………….. 2 …. [He] (each dot represents 1 electron)

Exercise Predict the electron configuration of the elemnt lead (#82), by filling with dots the energy levels (orbitals) in the above Aufbau diagram (max 2 per orbital as in the 1s)

2. Using dots (or arrows) to represent electrons. Fill in the following Aufbau diagrams.

	germanium	manganese	bromide ion	vanadium (V) ion
4p	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
3d	___ ___ ___ ___ ___	___ ___ ___ ___ ___	___ ___ ___ ___ ___	___ ___ ___ ___ ___
4s	___	___	___	___
3p	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
3s	___	___	___	___
2p	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
2s	___	___	___	___
1s	___	___	___	___

Using subshell notation, ($1s^2 2s^2$ etc) write complete electron configurations

Ge ________________________________ Mn___________________________________

Br^{-1}________________________________ V^{+5}________________________________

Now write abbreviated electron configurations using noble gas notation **[ ]** plus partially filled outer subshells. i.e. iron: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^6$; abbreviated as **[**Ar**]**$4s^2 3d^6$

Ge _______________________________ Mn _________________________________

Br^{-1} _______________________________ V^{+5} _______________________________

3. Write the electron configurations of these elements and their ions:

Al ___________________ Al^{+3}_________________

Cl _____________________ Cl^- __________________

Ba _____________________ Ba^{+2} __________________

As _____________________ As^{-3} _________________

V _____________________ V^{+3} ___________________

Sb _____________________ Sb^{+3}___________________ Sb^{+5} ___________________

4. Write symbols of three cations & three anions that are **isoelectronic** with neon: (isoelectronic means having the same number of electrons)

5. Write Lewis electron dot formulas showing the **valence electrons** of:
(Place the dots on the symbols)

O Se P Br Ga Sn [Bi $]^{-3}$ K [Ca $]^{+2}$ Cs