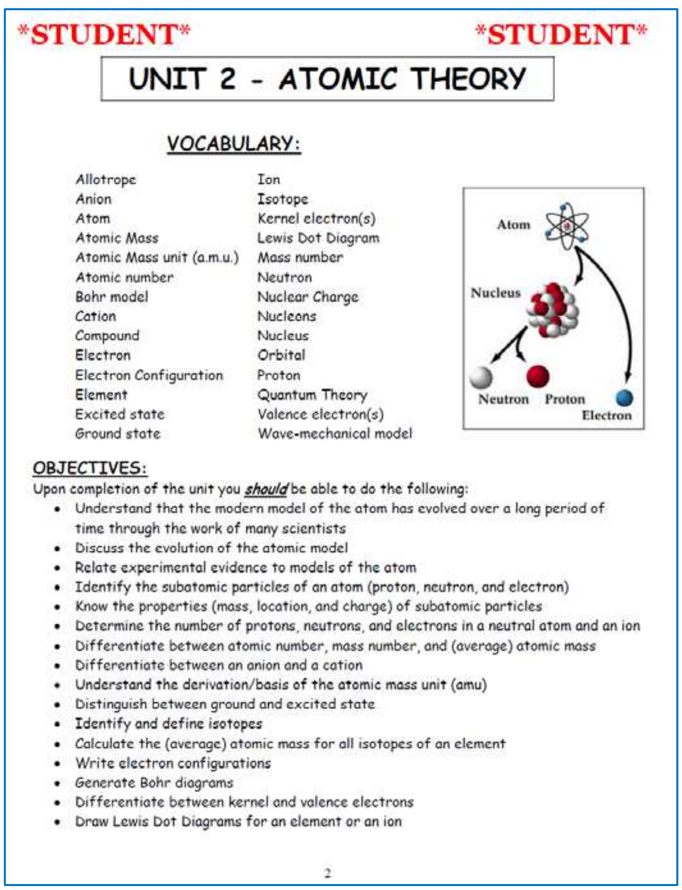
STUDENT *STUDENT*

Mr. Dolgos
Regents Chemistry

NOTE PACKET
Unit 2: Atomic Theory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UNIT 2 - ATOMIC THEORY

VOCABULARY:

Allotrope	Ion
Anion	Isotope
Atom	Kernel electron(s)
Atomic Mass	Lewis Dot Diagram
Atomic Mass unit (a.m.u.)	Mass number
Atomic number	Neutron
Bohr model	Nuclear Charge
Cation	Nucleons
Compound	Nucleus
Electron	Orbital
Electron Configuration	Proton
Element	Quantum Theory
Excited state	Valence electron(s)
Ground state	Wave-mechanical model

OBJECTIVES:
Upon completion of the unit you ***should*** be able to do the following:
- Understand that the modern model of the atom has evolved over a long period of time through the work of many scientists
- Discuss the evolution of the atomic model
- Relate experimental evidence to models of the atom
- Identify the subatomic particles of an atom (proton, neutron, and electron)
- Know the properties (mass, location, and charge) of subatomic particles
- Determine the number of protons, neutrons, and electrons in a neutral atom and an ion
- Differentiate between atomic number, mass number, and (average) atomic mass
- Differentiate between an anion and a cation
- Understand the derivation/basis of the atomic mass unit (amu)
- Distinguish between ground and excited state
- Identify and define isotopes
- Calculate the (average) atomic mass for all isotopes of an element
- Write electron configurations
- Generate Bohr diagrams
- Differentiate between kernel and valence electrons
- Draw Lewis Dot Diagrams for an element or an ion

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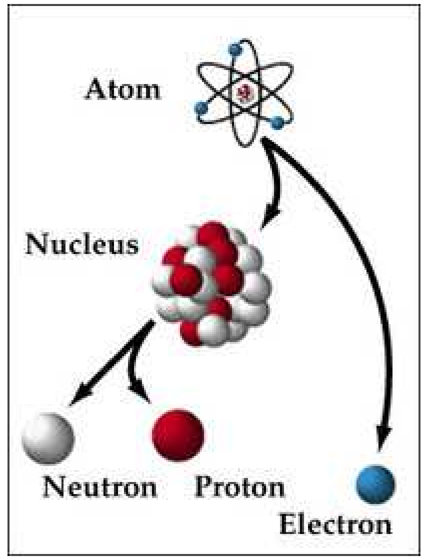
Element	Quantum Theory
Excited state	Valence electron(s)
Ground state	Wave-mechanical model
Ion	



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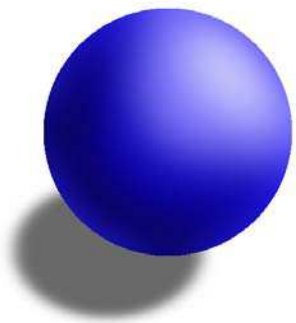
THE EVOLUTION OF THE ATOMIC MODEL

Atom = ____

____



Dalton (1803)

- Known as the _____________ of the atomic theory
- Dalton's Postulates: (**MEMORIZE!**)
  1. All matter is composed of indivisible particles called atoms
  2. All atoms of a given element are identical in mass and properties. Atoms of different elements have different masses and different properties
  3. Compounds are formed by a combination of 2 or more atoms
  4. Atoms cannot be created, destroyed, or converted into other kinds of atoms during chemical reactions

****** ____ ******

1. ________________________
2. ___________________________________

J.J. Thomson (1897)

http://highered.mcgraw-hill.com/sites/0072512644/student_view0/chapter2/animations_center.html

(Click link to see animation of Cathode Ray Tube Experiment)

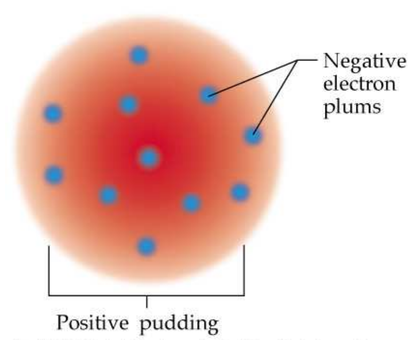
- Used a ______________________________ with charged electrical field (+/-)
- Cathode ray deflected ______________________ electrode
  ___________________________ electrode
- Discovered _____________________ called the ___________:
  - _____________
  - _____________________________

****** ____ ******

1. ________________________________
2. ____

(just like raisin bread)

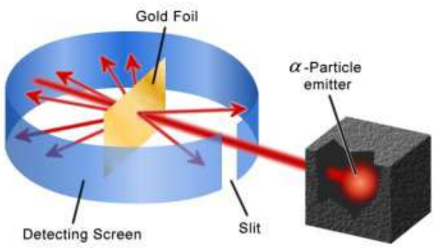
Thompson plum pudding model of the atom



J.J. Walker (1975)

http://www.youtube.com/watch?v=v19PpD5uqL0&safety_mode=true&persist_safety_mode=1&safe=active

(Click link to see one of my favorite TV catch phrases)



Rutherford (1909) *

http://www.mhhe.com/physsci/chemistry/essentialchemistry/flash/ruther14.swf

(Click link to see animation of Gold Foil Experiment)

- Conducted the ______________________ where he ______________ a thin piece of _______________ with a ____
- Expected virtually all alpha particles to pass straight through foil
- Most passed through, but some were severely deflected (see diagram above)
- Conclusion led to…

****** ____ ******

1. The _________ is ________________________
2. At the center of the atom is a __________________________ called the _____________

*Provided no information about electrons other than the fact that they were located outside the nucleus.

Neils Bohr (1913)

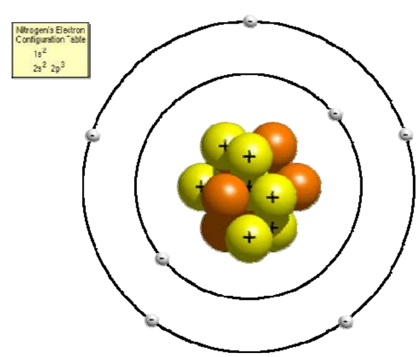
http://einstein.byu.edu/~masong/HTMstuff/Absorb2.html

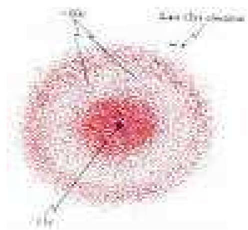
(Click link to see animation of the Bohr Model)

****** __________________ or ___________________________ ******

1. Electrons travel ___________ the nucleus in well-defined paths called ___________ (like planets in a solar system)
2. Electrons in _________________ possess ______________________ __________________
3. ____________________ a certain amount of ___________ causes electrons to ___________ to a ____________________ or an ______________________

   When ____________ electrons _______________ a certain amount of _________ causes electrons to _________________ to a ________________________ or the ____________________





Wave-Mechanical/Cloud Model

(Modern, present-day model)

http://www.chemeng.uiuc.edu/~alkgrp/mo/gk12/quantum/

- Electrons have distinct amounts of energy and move in areas called ________________
  - ORBITAL = an area of ______________________ for finding an ________________ (not necessarily a circular path)
- Developed after the famous discovery that energy can behave as both ___________ & ____________________
- ____________________________________ have contributed to this theory using ____________________________________

PRACTICE:

1. Which of the following did Rutherford's Gold Foil experiment prove?
   a. That the atom was a uniformly dense sphere.
   b. That the atom is mostly empty space with a dense, positive core.
   c. That most the atom consists of a uniform positive "pudding" with small negative particles called electrons embedded throughout.
   d. That electrons travel around the nucleus in well-defined paths called orbits.

2. J.J. Thomson's Cathode Ray Tube experiment led to the discovery of
   a. the positively charged subatomic particle called the electron
   b. the positively charged subatomic particle called the proton
   c. the positively charged subatomic particle called the electron
   d. the negatively charged subatomic particle called the electron

3. According to the Bohr Model,
   a. electrons are found in areas of high probability called orbitals
   b. electrons travel around the nucleus in circular paths called orbits
   c. electrons are found in areas of high probability called orbits
   d. electrons travel around the nucleus in random paths called orbitals

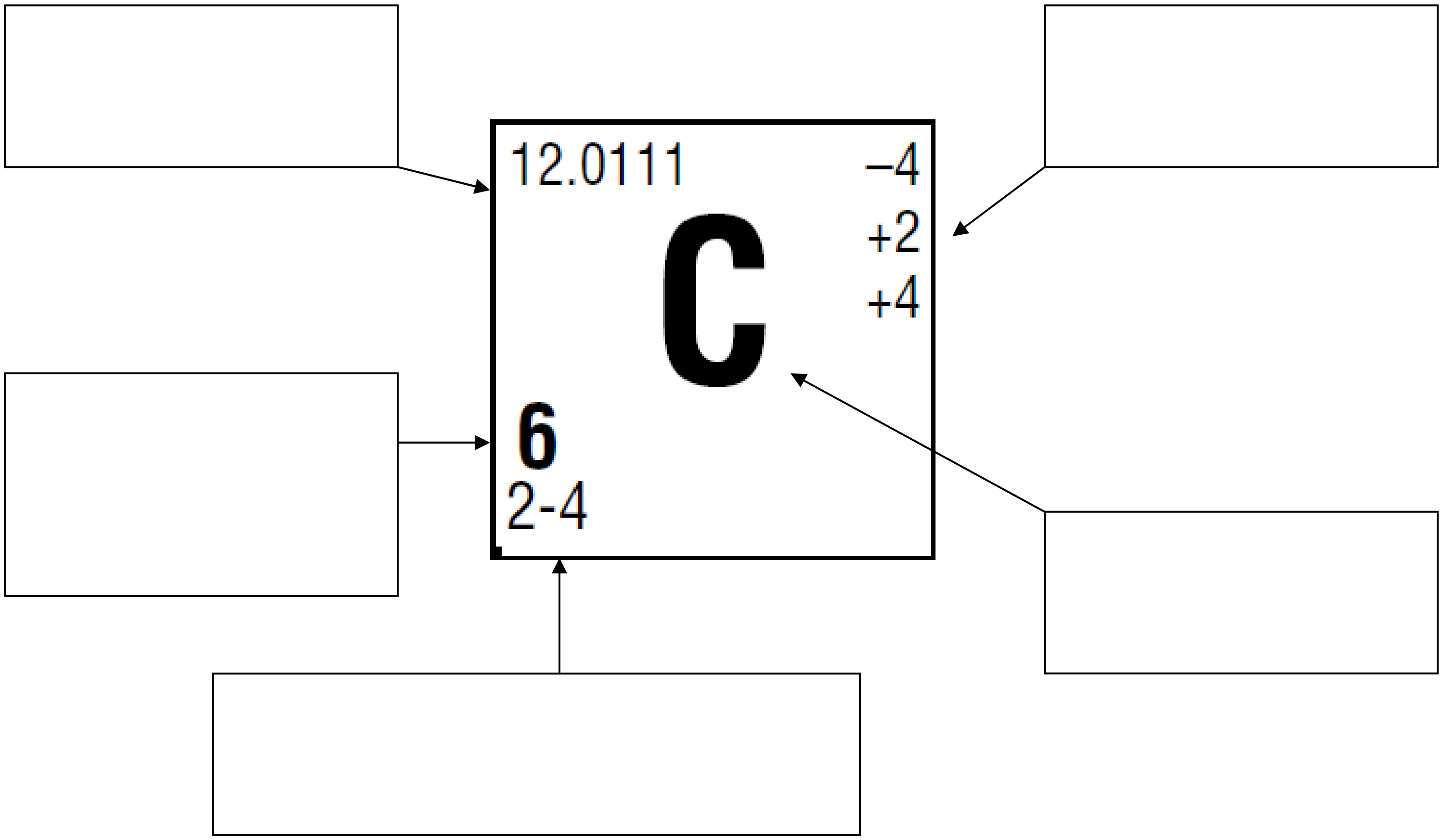
4. According to the Wave-Mechanical Model,
   a. electrons are found in areas of high probability called orbitals
   b. electrons travel around the nucleus in circular paths called orbits
   c. electrons are found in areas of high probability called orbits
   d. electrons travel around the nucleus in random paths called orbitals

5. Which of the following does not follow Dalton's Postulates?
    a. All atoms of a given element are identical
    b. All atoms look like a simple sphere
    c. Compounds are formed by combinations of 2 or more different elements
    d. Atoms of different elements have different properties and masses

6. When electrons in an atom gain or absorb enough energy, they can
    a. jump to the ground state
    b. fall back to the ground state
    c. jump to an excited state
    d. fall back to an excited state

7. When excited electrons lose or emit enough energy, they can
    a. jump to the ground state
    b. fall back to the ground state
    c. jump to an excited state
    d. fall back to an excited state

VOCABULARY (of the Periodic Table)



****Nucleons** = PROTONS and NEUTRONS; any subatomic particles found w/in the nucleus

Subatomic Particle	Charge	Relative Mass	Location	Symbol	How to Calculate
Proton				______	
Neutron					
Electron					

DETERMINING SUBATOMIC PARTICLES (p, n, e)

DIRECTIONS: Use the information below to complete the chart that follows.

 # Protons = ______________________________

 # Neutrons = ______________________________

 # Electrons = ______________________________

Atomic number = ______________________________

____

Mass # = ______________________________

Nuclear Charge = ______________________________

____

Symbol	# Protons	# Neutrons	# Electrons	Atomic Number	Mass Number	Nuclear Charge	Nuclear Symbol
Cl-35	17	18	17	17	35	17	$^{35}_{17}Cl$
	15	16					
C-14		8					
			8				$^{16}_{8}O$
Ar-40		22					
				20	40		

PRACTICE:

1. What is one thing about you that can always be used to identify you because it never changes?

2. Which of the numbers above is the one thing that can always be used to identify an element because it also never changes?

3. The total number of electrons in a neutral atom is the same as which number?

4. Which of the subatomic particles are located in the nucleus?

5. Which of the subatomic particles are located outside the nucleus?

6. Which of the subatomic particles have charge (+ or -)?

7. Which of the subatomic particles have mass?

8. What is the term for particles located in the nucleus?

9. If you know the element symbol (ex: F), which of the #'s from the previous chart do you AUTOMATICALLY know?

10. If you have the nuclear charge or the number of protons in a neutral atom, what other number(s) or information do you also know?

11. In a neutral atom, the number of which 2 subatomic particles is always the same?

ATOMS (neutral) VS. IONS (charged)

Vocabulary Term	Definition	Example/Diagram
Neutral Atom		
Ion	aNion	
	Ca+ion	

PRACTICE:

1. When a neutral atom gains an electron, it becomes a
   a. negative cation
   b. positive cation
   c. negative anion
   d. positive anion

2. When a neutral atom loses an electron, it becomes
   a. negative cation
   b. positive cation
   c. negative anion
   d. positive anion

3. What is the charge on a magnesium ion that has lost two electrons? ________

4. What is the charge on a fluoride ion that has gained one electron? ________

5. The chemical symbol S^{-2} represents a(n)
   a. cation formed as a result of a sulfur atom losing 2 electrons
   b. cation formed as a result of a sulfur atom gaining 2 electrons
   c. anion formed as a result of a sulfur ion losing 2 electrons
   d. anion formed as a result of a sulfur ion gaining 2 electrons

6. The chemical symbol Fe^{+3} represents
   a. cation formed as a result of a iron atom losing 3 electrons
   b. cation formed as a result of a iron atom gaining 3 electrons
   c. anion formed as a result of a iron ion losing 3 electrons
   d. anion formed as a result of a iron ion gaining 3 electrons

7. Give the correct chemical symbol for the ion formed when oxygen gains 2 electrons: ________

8. Give the correct chemical symbol for the ion formed when sodium loses one electron: ________

ISOTOPE = ____

____

____

Example 1: Isotopes of Carbon (C-12, C-13, & C-14)

$^{12}_{6}C$	$^{13}_{6}C$	$^{14}_{6}C$
p =	p =	p =
n =	n =	n =
e =	e =	e =

Example 2: Isotopes of Uranium (U-238, U-240)

U-238	U-240
p =	p =
n =	n =
e =	e =

Sample Questions:

1. Two different isotopes of the same element must contain the same number of
   a. protons b. neutrons c. electrons

2. Two different isotopes of the same element must contain a different number of
   a. protons b. neutrons c. electrons

3. Isotopes of a given element have
   a. the same mass number and a different atomic number
   b. the same atomic number and a different mass number
   c. the same atomic number and the same mass number

Calculating Atomic Mass (for any element):

Atomic Mass = the weighted average of an element's naturally occurring isotopes

(% abundance of isotope in decimal form) x (mass of isotope 1)
(% abundance of isotope in decimal form) x (mass of isotope 2)
+ (% abundance of isotope in decimal form) x (mass of isotope 3)

Average Atomic Mass of the Element

Ex 1: The exact mass of each isotope is given to you.
Chlorine has two naturally occuring isotopes, Cl-35 (isotopic mass 34.9689 amu) and Cl-37 (isotopic mass 36.9659 amu). In the atmosphere, 32.51% of the chlorine is Cl-37, and 67.49% is Cl-35. What is the atomic mass of atmospheric chlorine?

Step 1: Multiply the mass of each separate isotope by its percent abundance in DECIMAL FORM (move the decimal 2 places to the left)

Cl-35 = 34.9689 x (.6749) = 23.6005

Cl-37 = 36.9659 x (.3251) = 12.0176

** These are the *weighted masses* **

Step 2: Add up the products of all the calculated isotopes from step 1.

  23.6005
+ 12.0176

  35.6181

** This is your *average atomic mass* **

Ex 2: The exact mass for each isotope is NOT given to you.

The element Carbon occurs in nature as two isotopes. Calculate the average atomic mass for Carbon based on the information for the isotopes below.

^{12}C = 98.89% ^{13}C = 1.11%

**Since the exact masses were NOT given for either of the isotopes, just use the mass number instead. For ^{12}C, the mass would be 12 amu, and for ^{13}C, the mass would be 13.

Step 1: Multiply the mass of each separate isotope by its percent abundance in DECIMAL FORM (move the decimal 2 places to the left)

^{12}C = 12 x (.9889) = 11.8668

^{13}C = 13 x (.0111) = 0.1443

** These are the *weighted masses* **

Step 2: Add up the products of all the calculated isotopes from step 1.

$$\begin{array}{r} 11.8668 \\ +\ 0.1443 \\ \hline 12.0111 \end{array}$$

** This is your *average atomic mass* **

Practice 1: The element Boron occurs in nature as two isotopes. In the space below, calculate the average atomic mass for Boron.

Isotope	mass	percent abundance
Boron-10	10.0130 amu	19.9%
Boron-11	11.0093	80.1%

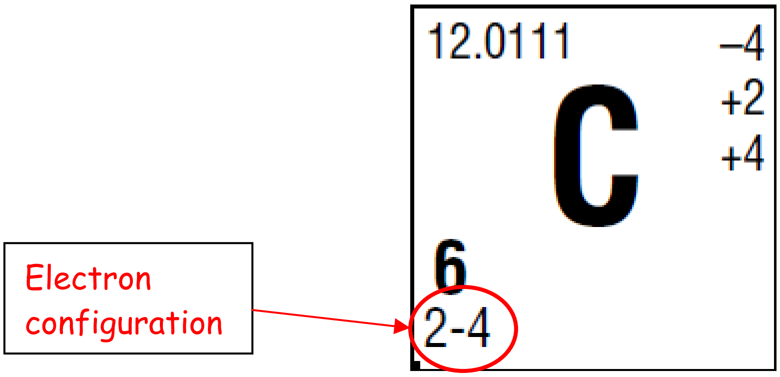
Practice 2: The element Hydrogen occurs in nature as three isotopes. In the space below calculate the average atomic mass for Hydrogen.

Isotope of Hydrogen	Percent Abundance
$^{1}_{1}H$ Protium	99.0%
$^{2}_{1}H$ Deuterium	0.6%
$^{3}_{1}H$ Tritium	0.4%

Mass Number	Atomic Mass
The ______ of ____________________ of a given element.	The ______________________ of ____________________ of a given element

ELECTRON CONFIGURATIONS = a dashed chain of numbers found in the ____________________________ of an element box (see below); tells us the number of _____________________ as well as the number of _______________ in each level (tells us how the electrons are arranged around the nucleus)

http://www.lon-capa.org/~mmp/period/electron.htm



*All electron configurations on the Periodic Table are _________________ **(p=e)**

**For ________, add or subtract electrons from the ______________________ in the electron configuration only

SUBSTANCE	ELECTRON CONFIGURATION
Magnesium	2-8-2
Mg^{+2}	2-8
Bromine	
Br^{-1}	
Barium	
*Lead	

* shortcut allows you to cut out the first two orbitals to shorten the "address"

Valence Electrons:

- electrons found in the _______________________ shell or orbital
- the ____________ number in the electron configuration

Kernel Electrons:

- ________________ electrons (all non-valence electrons)

Ex:	Practice 1:	Practice 2:
Chlorine	**Nitrogen**	**Sodium**
# valence e^- = 7	# valence e^- =	# valence e^- =
# kernel e^- = 10	# kernel e^- =	# kernel e^- =

Principle Energy Level (n) = electron energy levels consisting of ________________ which are designated ___, ___, ___ or ___.

Element	e-configuration	
Helium		1s __
Carbon		1s __ 2s __ 2p __ __ __
Sulfur		1s __ 2s __ 2p __ __ __ 3s __ 3p __ __ __ 3d __ __ __ __ __

Sample question: What is the maximum number of electrons that can occupy the 3rd principal energy level in any atom? ____________________

PRACTICE:

1. Give the correct electron configuration for an atom of oxygen. ________________
2. Give the correct electron configuration for the K^{+} ion. ________________
3. How many valence electrons are there in atom of fluorine? _________
4. How many valence electrons are there in an F^{-} ion? _________
5. How many kernel electrons are there in a phosphorus atom? _________
6. How many valence electrons are there in a phosphorus atom? _________
7. How many principal energy levels are there in a Bromine atom? _________

BOHR DIAGRAMS (one method for expressing electron location in an atom or ion);
____________________ MUST be drawn → BOHRing

1. Look up electron configuration of element at hand on Periodic Table. If you are working with an ion, add/subtract the proper amount of electrons the last or VALENCE number in the configuration.

   Example: Oxygen is 2-6

2. Draw a square for the nucleus and notate correct amount of protons and neutrons inside using the letters P and N. For oxygen, it would be P8 and N8.

3. Using rings or shells, place the proper number of ORBITS around your nucleus. The number of orbits is equal to the number of principal energy levels. However many numbers there are in the electron configuration is the number of orbits you need to draw. Oxygen has 2 principal energy levels, so it has 2 orbits outside the nucleus.

4. Look at the 1^{st} number in the electron configuration. Using either an "x" or a dot to represent your electrons, place that many electrons in the ORBIT CLOSEST TO THE NUCLEUS ONLY. You can have a maximum of 2 e^- in the first orbit.

5. Look at the next number in the electron configuration. Using either an "x" or a dot to represent your electrons, place that many electrons in the next orbit in the areas that would correspond to the numbers 12, 3, 6, and 9 on the face of a clock.

6. If there are any electrons remaining in the configuration, pair them up with electrons you have already placed in the current shell. You may have no more than 2 e^- in any of the 4 spots.

7. Repeat steps 6 and 7 for any remaining orbits.

   ****You may have no more than 8 e^- total in the outermost or valence orbit****

PRACTICE: Complete the following electron configurations and Bohr diagrams.

Carbon e$^-$ config: ____________	F^- e$^-$ config: ____________
Na^+ e$^-$ config: ____________	Argon e$^-$ config: ____________
Al e$^-$ config: ____________	S^{2-} e$^-$ config: ____________

LEWIS (ELECTRON) DOT DIAGRAMS

(Only illustrates ____)

1. Write the element's symbol

2. Retrieve electron configuration from Periodic Table. The last number in the configuration is the ____

3. Using either an "x" or a dot to represent your electrons, place that many electrons in the next orbit in the areas that would correspond to the numbers 12, 3, 6, and 9 on the face of a clock.

   Ex: __________ OR

4. If you are working with an ION you must adjust the valence electrons (add or subtract electrons) in the configuration before constructing your Dot Diagram. Your final diagram must include brackets and the charge on the ion.

Ex 1: S^{-2}	**Ex 2: K^{+1}**
__________ to the 6 that S normally has in its valence shell.	_______________ from the valence shell of K.
* _______________ always end up with _____________ ____________________	* _______________ always end up with _____________ ____________________

Draw LEWIS ELECTRON-DOT DIAGRAMS for the following:

Argon	Phosphorus	Silicon	Beryllium	Oxygen
Aluminum	Sodium	N^{3-}	Na^{1+}	O^{2-}

QUICK NOTE:

- The number of ______________________________ is equal to the number of ____________ that an element can form with other elements.
- When determining the number of bonds an element can form, arrange the valence electrons so that you have the ___________ number __________.

  Ex: Carbon can be arranged in either of the two ways shown on the previous page. Draw the Lewis dot structure for carbon that gives it the maximum number of ______________ valence electrons.

  How many bonds can an atom of carbon form? ____

- The alternate Lewis structure for carbon with only 2 unpaired valence electrons represents the _______________________________.

PRACTICE:

1. What is the advantage to using the Bohr model as opposed to the Lewis model?
    a. The Bohr model provides more information than the Lewis model.
    b. The Bohr model is less bulky than the Lewis model.
    c. The Bohr model shows the valence electrons.
    d. The Bohr model shows how many bonds atoms of an element can form.

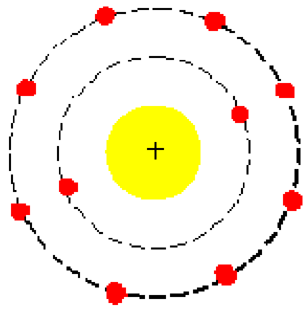
2. What is the advantage to using the Lewis model as opposed to the Bohr model?
    a. The Lewis model provides more information than the Bohr model.
    b. The Lewis model is less bulky than the Bohr model.
    c. The Lewis model shows the valence electrons.
    d. The Lewis model shows how many bonds atoms of an element can form.

3. What is the maximum number of electrons an atom or an ion can have in its valence shell?
    a. 2
    b. 4
    c. 6
    d. 8

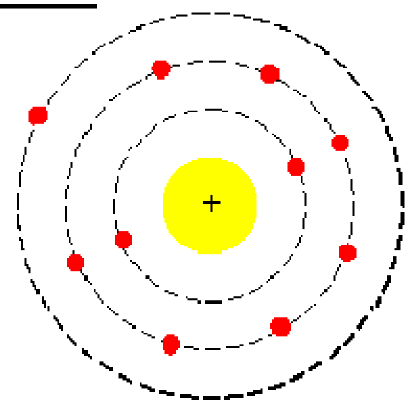
4. The number of bonds an atom of an element can form is the same as the number of
    a. electrons in its valence shell.
    b. paired electrons in its valence shell.
    c. unpaired electrons in its valence shell.

5. An atom of which of the following elements can form the most bonds? (Hint: Look at your Lewis diagrams)
    a. Phosphorus
    b. Oxygen
    c. Sodium
    d. Carbon

Ground State vs. Excited State



Neon
2-8
(ground state electron configuration)



Neon
2-7-1
(excited state electron configuration)

*Notice that one electron from the 2nd orbital has moved to the 3rd orbital

Ground State = electrons in ______________________________ possible (the configuration ______________________________)

→ ground state electron configuration for Li is 2-1

Excited State = electrons are ______________________________ ____________________ (______ configuration ____________________)

→ excited state electron configuration for Li could be 1-2, 1-1-1

Distinguish between ground state and excited state electron configurations below:

Bohr Electron Configuration	Ground or Excited state?
2-1	**Ground**
2-0-1	**Excited**
1-1-1	
2-7-3	
2-8-2	
2-8-8-2	
2-8-17-6	
2-8-18-8	
2-6-18-1	
2-5-18-32	

***The greater the distance from the nucleus, the greater the energy of the electron

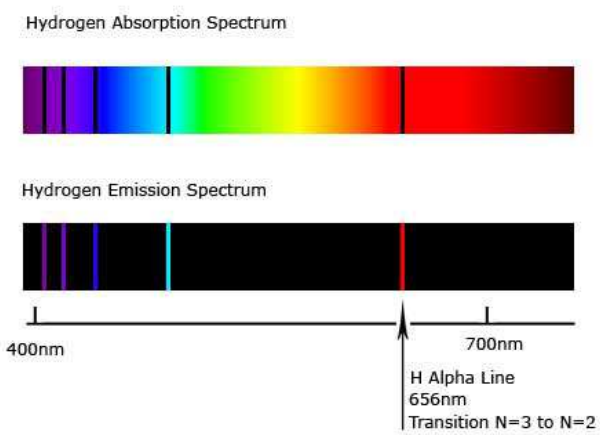
- When ______________________________ they jump to a __________ energy level or an ______________________.
    - ✓ This is a very ___________________________ condition
- ______________________ rapidly ___________________ or _______ to a ___________ energy level
    - ✓ When excited electrons fall from an excited state to lower energy level, they release energy in the form of _________.

_____________ → _____________

- Energy is _____________
- ___________________________ is produced

_____________ → _____________

- Energy is _____________
- ___________________________ is produced



_____________ show the specific wavelengths of light being _________ by the electrons (becoming excited)

_____________ show the specific wavelengths of light being _________ by the electrons (falling down)

- ✓ Balmer Series: electrons falling from an _______________ down to the __________________ give off _____________ light (AKA "Bright Line ______________" or "Visible Light _______________")
    - Different elements produce different colors of light or ________________.
    - These spectra are _____________ for each element (just like a human fingerprint is unique to each person).
    - We use spectral lines to identify different elements.

Practice:

1. Which of the following is a ground state electron configuration?
   a. 2-7-2
   b. 2-7-3
   c. 2-6-1
   d. 2-8-1

2. Which of the following is an excited state electron configuration?
   a. 2-8-2
   b. 2-8-3
   c. 2-6-1
   d. 2-8

3. Give one possible example of an excited state electron configuration for oxygen: ______________________

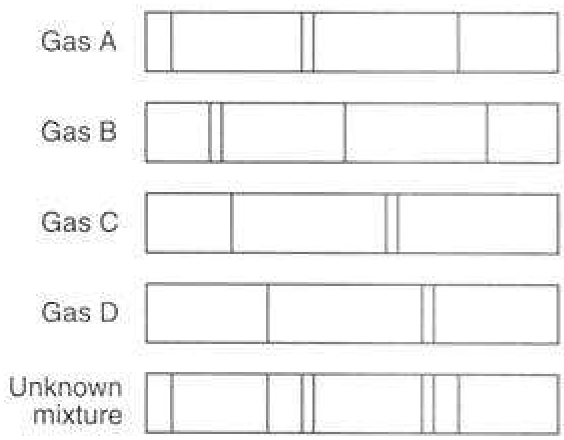
4. When atoms of an element in the ground state absorb enough energy, some of their electrons may
   a. fall back to the ground state and give off energy in the form of light.
   b. fall back to an excited state and give off energy in the form of light
   c. jump to the ground state.
   d. jump to an excited state.

5. When excited electrons lose enough energy, they will
   a. fall back to the ground state and give off energy in the form of light.
   b. fall back to an excited state and give off energy in the form of light
   c. jump to the ground state.
   d. jump to an excited state.

6. A dark-line spectrum is produced by
   a. electrons emitting energy and falling back to the ground state.
   b. electrons absorbing energy and falling back to the ground state.
   c. electrons absorbing energy and jumping to an excited state.
   d. electrons emitting energy and jumping to an excited state.

7. A bright-line spectrum is produced by
    a. electrons emitting energy and falling back to the ground state.
    b. electrons absorbing energy and falling back to the ground state.
    c. electrons absorbing energy and jumping to an excited state.
    d. electrons emitting energy and jumping to an excited state.

8. Based on the known bright line spectra produced by the four gases below, which gases are present in the unknown mixture?



Gases present: ___________

What to Study for the Atomic Exam (Unit 2)

- ✓ Structure of the atom (role/nature of the nucleus and electrons etc.)
- ✓ Gold Foil Experiment (know what was observed and the conclusions that were drawn from these 2 observations)
- ✓ Orbit vs. orbital (what is the difference?)
- ✓ Location, mass, charge of protons, neutrons, and electrons in an atom (see chart in notes)
- ✓ Isotopes (same element; different number of neutrons or masses ex: C-12 & C-14) – be able to identify them
- ✓ Nucleons (the subatomic particles found in the nucleus)
- ✓ Nuclear Charge (charge inside the nucleus; always positive and directly dependent on # protons)
- ✓ Chemical notations: where do we find the atomic #, mass #, atomic mass etc.
- ✓ Determining the number of protons, neutrons, and electrons (pne) in an atom or ion (use mass # or atomic mass rounded to whole number) – remember that the # protons ALWAYS tell us the symbol/element we have
- ✓ Atomic mass – weighted average mass of an element's naturally occurring isotopes (ex: C is 12.011)
- ✓ Ground state vs. excited state and the energy absorbed/released during electron movement (remember: light is emitted or seen when an electron jumps from an excited state back down to ground state or a lower energy level)
- ✓ Principle energy levels (orbitals) and the maximum # electrons found in each – use $2n^2$ formula
- ✓ Calculating average atomic mass given isotope abundances and masses
- ✓ The nucleus makes up pretty much all the mass in an atom – therefore (mass #) = (#protons) + (#neutrons)
- ✓ Who performed the cathode ray experiment? What subatomic particle was discovered in this experiment?
- ✓ Atom vs. Ion (what is the difference?)
- ✓ Electron Configuration – found below the atomic number on PTable (know how to write them for an atom or ion)
- ✓ Drawing Bohr models – show all the electrons within an atom/ion and their location (construct nucleus & use shells or circles to place electrons)
- ✓ Lewis Dot Diagrams – write element symbol and distribute dots around (draw only the valence electrons)