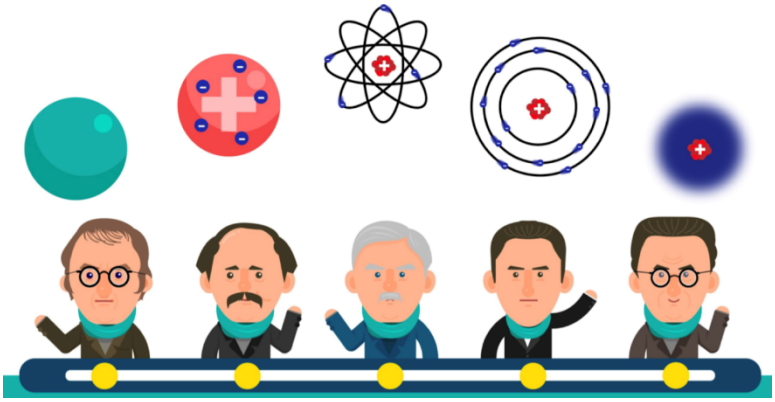
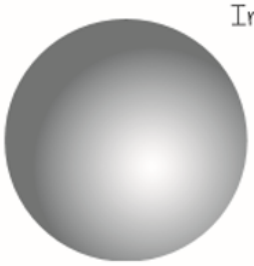
OBJECTIVE #1:

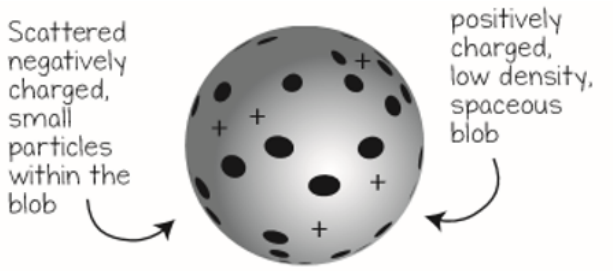
The history on how the atom came to be….





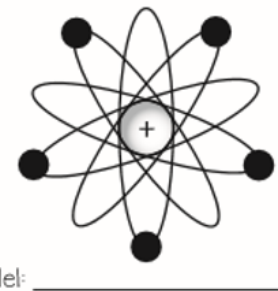
1a. Model: _____

b. Scientist(s) responsible: _____



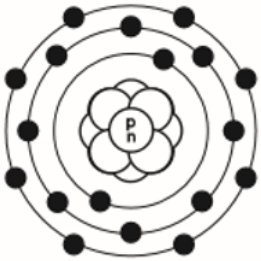
2a. Model: _____

b. Scientist(s) responsible: _____



3a. Model: _____

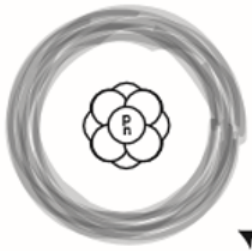
b. Scientist(s) responsible: _____



Nucleus with protons, neutrons, and electrons that orbit at defined energy levels and distances away from the nucleus

4a. Model: _____

b. Scientist(s) responsible: _____



Nucleus with electrons that have calculated probable areas where they are located, but no exact location can be determined.

5a. Model: _____

b. Scientist(s) responsible: _____

1) The discovery of the electron as a subatomic particle was a result of

1) collision theory
2) kinetic molecular theory
3) the gold-foil experiment
4) experiments with cathode ray tubes

2) Which statement describes the charge and location of an electron in an atom?

1) An electron has a positive charge and is located outside the nucleus.
2) An electron has a positive charge and is located in the nucleus.
3) An electron has a negative charge and is located outside the nucleus.
4) An electron has a negative charge and is located in the nucleus.

3) Given a list of atomic model descriptions:

A: electron shells outside a central nucleus
B: hard, indivisible sphere
C: mostly empty space

Which list of atomic model descriptions represents the order of historical development from the earliest to most recent?

1) *A*, *B*, *C*
2) *A*, *C*, *B*
3) *B*, *C*, *A*
4) *B*, *A*, *C*

4) Which statement describes the location of protons and neutrons in an atom of helium?

1) Protons and neutrons are in the nucleus.
2) Protons and neutrons are outside the nucleus.
3) Protons are outside the nucleus, and neutrons are in the nucleus.
4) Protons are in the nucleus, and neutrons are outside the nucleus.

5) Compared to the entire atom, the nucleus of the atom is

1) smaller and contains most of the atom's mass
2) smaller and contains little of the atom's mass
3) larger and contains most of the atom's mass
4) larger and contains little of the atom's mass

6) Which two particles have opposite charges?

1) an electron and a neutron
2) an electron and a proton
3) a proton and a neutron
4) a proton and a positron

7) According to the wave-mechanical model, an orbital is defined as the most probable location of

1) a proton
2) a neutron
3) a positron
4) an electron

OBJECTIVE #2: Identifying Subatomic Particles in an atom

The atom is made up of three main subatomic particles: protons, electrons and neutrons.

A) **Protons (p^+)**

- _____ charged particles
- Found _____ the nucleus
- Has an approximate mass of _____
- # of protons provides the _____ and the _____ of the atom

B) **Neutrons (n^0)**

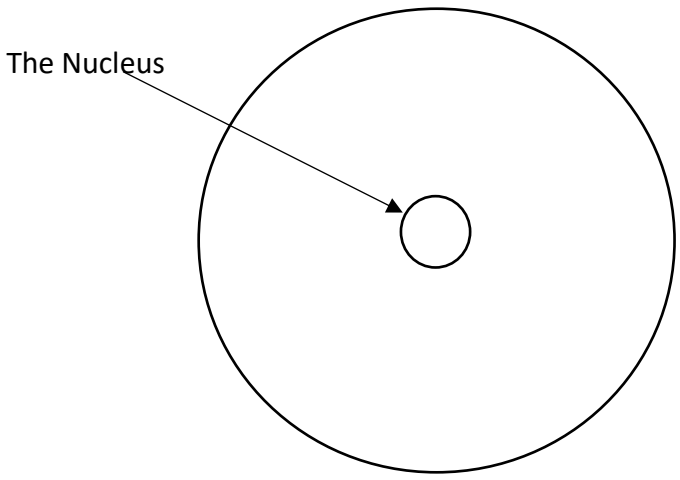
- _____ charged particles
- Found _____ the nucleus
- Has an approximate mass of _____
- Neutrons lend to the _____ of the nucleus and help hold the protons together

C) **Electrons (e^-)**

- _____ charged particles
- Found _____ the nucleus
- Have an approximate mass of _____
- If the # of electrons is the same as the # of protons, an atom is _____

Subatomic particle	Proton	Electron	Neutron
Symbol			
Charge			
Mass			
Location			

An Atom (not drawn to scale)



OBJECTIVE #3: Determining the Number of Subatomic Particles

A) For a NEUTRAL atom, the periodic table is necessary to determine the number of protons, electrons and neutrons

a) # of Protons = the _____ on the periodic table

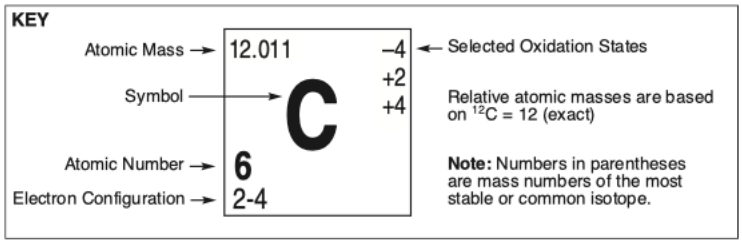
b) Electrons = the sum of the numbers in the _____

- Will be the same as the number of protons (atomic number) in a *neutral* atom

c) Neutrons = mass number – atomic number = # of neutrons

this is the atomic mass rounded to a whole #

- The **mass number** is the protons and neutrons combined



1. A neutral atom contains 12 neutrons and 11 electrons. The number of protons is this atom is:
   1. 1 2. 11 3. 12 4. 23

2. An atom is electrically neutral because the
   1. number of protons equals the number of electrons
   2. number of protons equals the number of neutrons
   3. ratio of the number of neutrons to the number of electrons is 1:1
   4. ratio of the number of neutrons to the number of protons is 2:1

3. The number of neutrons in an atom of iodine is:
   1. 53 2. 73 3. 74 4. 127

4. Which notation represents an atom of sodium with an atomic number of 11 and a mass number of 24?
   1. $^{24}_{11}Na$ 2. $^{11}_{24}Na$ 3. $^{13}_{11}Na$ 4. $^{35}_{11}Na$

5. The total mass of the protons in an atom of gold is approximately:
   1. 79 amu 2. 119 amu 3. 198 amu 4. 277 amu

6. What is the total number of electrons in an atom of potassium?
   1. 18 2. 19 3. 20 4. 39

7. What is the mass number of a carbon atom that contains six protons, eight neutrons, and six electrons?
   1. 6 2. 8 3. 14 4. 20

8. Which statement best describes the nucleus of an aluminum atom?
   1. It has a charge of +13 and is surrounded by a total of 10 electrons.
   2. It has a charge of +13 and is surrounded by a total of 13 electrons.
   3. It has a charge of –13 and is surrounded by a total of 10 electrons.
   4. It has a charge of –13 and is surrounded by a total of 13 electrons.

B) For a charged atom, known as an _____, the periodic table is still necessary to determine the number of protons, neutrons and electrons. However, an atom becomes charged ONLY when it has lost or gained _____

** This can happen during chemical bonding**

a) Protons = the atomic number on the periodic table

b) Neutrons = mass number – atomic number = # of neutrons

c) Electrons = ?

If an atom has lost electrons through bonding, it will have more protons than electrons (#p+ > #e-)

- since there will be more positively charged protons than negatively charged electrons, the atom will have an overall _____ charge

- This is known as a _____

If an atom has gained electrons through bonding, it will have more electrons than protons (#e- > #p+)

- since there will be more negatively charged electrons than positively charged protons, the atom will have an overall _____ charge

- This is known as a _____

1. Fill in the table below appropriately

Name	Symbol	Protons	Neutrons	Electrons	Atomic #	Mass #
Barium ion	Ba^{+2}				56	137
	K^{+}					39
Gold ion	Au^{+3}		118		79	
Chloride ion	Cl^{-}		18	18	17	
Fluoride ion			10			
Sulfide ion	S^{-2}		16			

2. When a lithium atom forms an Li^{+} ion, the lithium atom:

1. gains a proton 2. gains an electron 3. loses a proton 4. loses an electron

3. As an atom becomes an ion, its mass number:

1. decreases 2. increases 3. remains the same

4. An atom contains 16 neutrons, 15 protons and 18 electrons. What is the overall charge of the atom?

1. -3 2. 0 3. +3 4. +15

OBJECTIVE #4: Define and Determine Atoms that are Isotopes

Isotopes are atoms of the same element with the same number of _____ and

_____, but a different number of _____ (and therefore mass number)

Ex) Isotopes of Oxygen

O-16	O-17	O-18
$^{16}O_8$	$^{17}O_8$	$^{18}O_8$
p=	p=	p=
e=	e=	e=
n=	n=	n=

Ex) Isotopes of Hydrogen

H-1	H-2	H-3
$^{1}H_1$	$^{2}H_1$	$^{3}H_1$
p=	p=	p=
e=	e=	e=
n=	n=	n=

Each isotope makes up certain percent abundance amount out of 100% here on earth. These percent abundances are referenced and cannot be changed.

Almost all elements on the periodic table have isotopes, which each have different percent abundances. We can use this information to determine the weighted average atomic mass (WAAM) for each natural element.

Isotope Questions

1. Which symbols represent atoms that are isotopes of each other?
   a) ^{14}C and ^{14}N b) ^{16}O and ^{18}O c) ^{131}I and ^{131}I d) ^{222}Rn and ^{222}Ra

2. A neutral atom with 6 protons and 8 neutrons is an isotope of
   a) carbon b) silicon c) nitrogen d) oxygen

3. Which atoms have the same number of neutrons?
   a) H-1 and He-3 b) H-2 and He-4 c) H-3 and He-3 d) H-3 and He-4

4. Atoms of ^{14}N and ^{15}N have the same number of
   a) neutrons but a different number of protons
   b) protons but a different number of neutrons
   c) protons but a different number of electrons
   d) electrons but a different number of protons

5. All isotopes of neutral atoms of sodium have
   a) 11 protons and 12 neutrons
   b) 12 protons and 11 neutrons
   c) 11 protons and 11 electrons
   d) 12 protons and 12 electrons

6. There are three isotopes of hydrogen, H-1, H-2 and H-3. All of these isotopes have
   a) a mass of 2 amu
   b) an atomic number of 1
   c) 1,2 or 3 neutrons
   d) 1,2 or 3 protons

OBJECTIVE #5: Calculating the Weighted Average Atomic Mass (WAAM) of an atom

The reported atomic mass for each element on the periodic table is the weighted average mass of ALL of the naturally occurring stable isotopes of an element. It can be found by multiplying the atomic mass of the atom by the percent abundances (given to you) and adding the results.

WAAM =

Weighted Average Atomic Mass

*This formula is the only formula NOT GIVEN on Reference Table T - *It must be memorized* !!
** The final answer should reflect the most abundant isotope and should be in the range of the original isotope masses!!

Sample WAAM Problems

1. There are two isotopes of bromine. Br-79 makes up 50.69% of naturally occurring bromine, and Br-81 makes up 49.31.%. What is the weighted average atomic mass of bromine?

2. There are three isotopes of Ne. Ne-20 makes up 90.48% of all Ne and has a mass of 19.992 grams, Ne-21 makes up 0.27% of all Ne and has a mass of 20.993 grams, and Ne-22 makes up 9.25% of all Ne and has a mass of 21.991 grams. What is the weighted average atomic mass of Neon?

3. The average atomic mass of chlorine is 35.5 amu. Which mixture of isotopes (shown as percent's) produces this mass?

a) 50% C-12 and 50% C-13
b) 50% Cl-35 and 50% Cl-37
c) 75% Cl-35 amd 25% Cl-37
d) 75% C-12 amd 25% C-13

OBJECTIVE #6: Understanding the Bohr Model

A) Development of the Atom

- Electrons are placed in _____ or principal _____ _____around the nucleus
  * these are a fixed pathway around the nucleus, each with a designated amount of energy assigned to it
    ** lowest energy orbit is the one _____ to the nucleus; highest energy orbit is the one _____ from the nucleus

Rules when placing electrons around the nucleus: (remember this is not the most modern model!!)

a) On the periodic table, look at an atom's _____. This will give you the number of electrons that reside in each energy level around the nucleus
   - The electron configurations are written in _____, which is when electrons are in the lowest energy configurations possible

b) Begin filling lower energy levels first (those closest to the nucleus)

c) Must completely fill lowest energy level before beginning next energy level; since electrons repel each other, they should be evenly spaced in each orbit

d) Stop when all electrons are placed in appropriate orbit

- the last number in an electron configuration is called the _____ _____; this is used to determine chemical properties and will be the electrons available for chemical bonding

Bohr diagrams show the number of protons and neutrons in the nucleus and the number of electrons in their energy levels. The electron configuration shows how many electrons are in each level in the ground state, or under normal conditions.

Formula: $2n^2$

(where "n" is the energy level)

Energy level (n)	# of e- ($2n^2$)
n = 1	
n = 2	
n = 3	
n = 4	

1. How do the energy and the most probable location of an electron in the third orbit of an atom compare to the energy and most probable location of an electron in the first orbit of the same atom?

a) In the third shell, an electron has more energy and is closer to the nucleus
b) In the third shell, an electron has more energy and is farther from the nucleus
c) In the third shell, an electron has less energy and is closer to the nucleus
d) In the third shell, an electron has less energy and is farther from the nucleus

2. Compared to an electron in the first electron shell of an atom, an electron in the second shell of the same atom has

a) less mass b) less energy c) more mass d) more energy

3. What is the electron configuration of a silicon atom in ground state?

a) 2 – 4 b) 2 – 6 c) 2 – 4 – 8 d) 2 – 8 – 4

4. Which principal energy level can hold a maximum of eight electrons?

a) 1 b) 2 c) 3 d) 4

5. Which atom has seven valence electrons and a total of seventeen electrons overall?

a) C b) Cl c) Si d) P

6. An atom contains a total of 29 electrons. When the atom is in the ground state, how many different principal energy levels will contain electrons?

a) 1 b) 2 c) 3 d) 4

7. The principal energy level of the valence electron of an atom in the ground state is n = 3. What is the total number of occupied energy levels contained in this atom?

a) 1 b) 2 c) 3 d) 4

8. Which element has atoms with only one *completely* filled principal energy level?

a) N b) P c) As d) Sb

9. In a sulfur atom in the ground state, which energy level contains the most electrons?

a) 1 b) 2 c) 3 d) 4

10. Which electron configuration represents an atom of an element having a completed third principal energy level?

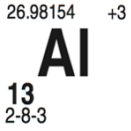
a) 2-8-10-2 b) 2-8-6-2 c) 2-8-18-2 d) 2-8-2

OBJECTIVE #7: Understanding the Difference between Ground State and Excited State

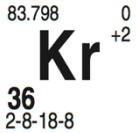
A) Ground State (GS): most _____ electron arrangement around the nucleus

- All electron configurations given on the periodic table are in ground state
- Electrons are in their lowest* possible energy locations in their designated energy levels

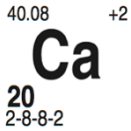
Examples of Ground State:



Al = 2 – 8 – 3



Kr = 2 – 8 – 18 – 8



Ca* = 2 – 8 – 8 – 2

B) Excited State (ES): If energy (heat, light, electricity) is added to an atom in ground state, the electrons of that atom can _____ that energy and jump to _____ unfilled principal energy levels

- This is a temporary move
- Very _____ arrangement of electrons around the nucleus
- An energy level cannot exceed the maximum amount of electrons (2 – 8 – 18 – 32)
- Electrons quickly then move back to ground state and _____ the exact amount of energy gained (Law of Conservation of Energy)

*** Excited State electron configuration will NOT match the configuration on the Periodic Table*

1. Compared to an atom of hydrogen in the ground state, an atom of hydrogen in the excited state has

a) absorbed energy b) released energy c) neither released nor absorbed energy

2. Which electron configuration represents an atom of lithium in an excited state?

a) 1-2 b) 2-1 c) 2-2 d) 1-1

3. Which electron configuration represents an atom in an excited state?

a) 2-8-2 b) 2-8-1 c) 2-8 d) 2-7-2

4. Which electron configuration represents an atom of aluminum in an excited state?

a) 2-7-4 b) 2-7-7 c) 2-8-3 d) 2-8-6

4. Which electron configuration could represent a strontium atom in an excited state?

a) 2–8–18–7–1 b) 2–8–18–7–3 c) 2–8–18–8–1 d) 2–8–18–8–2

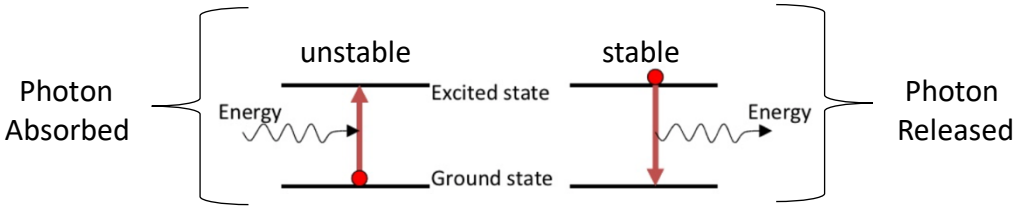
OBJECTIVE #8: Understanding how Atoms emit Visible Light

When energy (heat, light, electricity) is added to an atom, electrons in "ground state" will absorb that energy and jump to higher unfilled energy levels. The atom is then in "excited state".

- Being in excited state is unstable, and electrons MUST return back to their original energy levels

- When electrons return back to original energy levels, the same amount of energy that was initially absorbed is now released
  - This energy is released as photons (particles) of _____
  - The spectrum of colors is known as _____
  - The color produced by an electron depends on the distance an electron moves from excited state back to ground state.

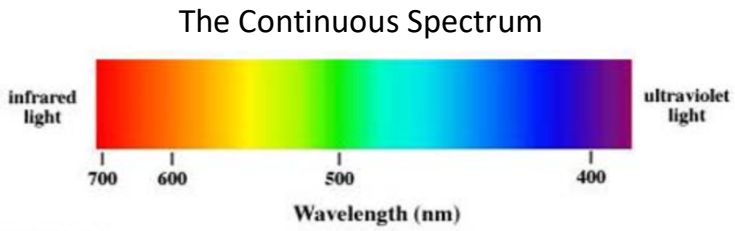
The Process:

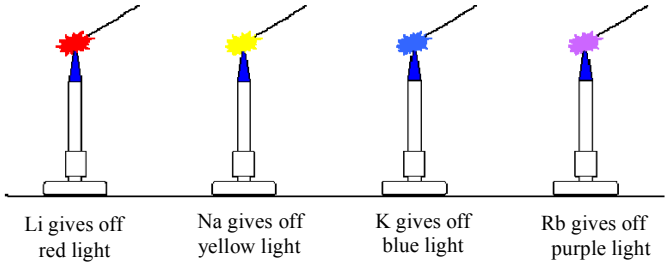


The color of the visible light spectrum (red, orange, yellow, green, blue, indigo or violet) emitted/seen depends on the energy transition & the distance an electron traveled from excited state to ground state

- The color RED represents a _____ energy transition
  - The distance an electron traveled is _____
- The color VIOLET represents a _____ energy transition
  - The distance an electron traveled is _____

To the naked eye, the light photons given off by electrons returning to ground state is seen as a one of the colors of the _____ spectrum





1. The characteristic bright-line spectrum of an element occurs when electrons
   a) move from lower to higher energy levels
   b) move from higher to lower energy levels
   c) are lost by a neutral atom
   d) are gained by a neutral atom

2. The light produced by signs using neon gas results from electrons that are
   a) moving from a higher to a lower principal energy level
   b) moving from a lower to a higher principal energy level
   c) being lost by the Ne(g) atoms
   d) being gained by the Ne(g) atoms

3. During a flame test, ions of a specific metal are heated in the flame of a gas burner. A characteristic color of light is emitted by these ions in the flame when the electrons
   a) gain energy as they return to lower energy levels
   b) gain energy as they move to higher energy levels
   c) emit energy as they return to lower energy levels
   d) emit energy as they move to higher energy levels

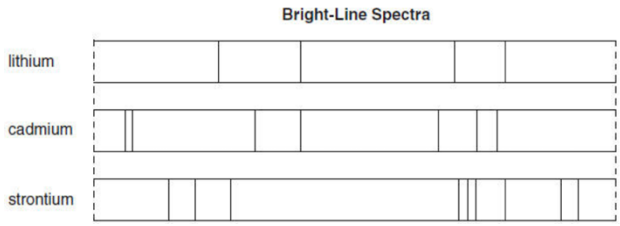
4. As an electron in an atom moves from the ground state to the excited state, the electron
   a) gains energy as it moves to a higher energy level
   b) gains energy as it moves to a lower energy level
   c) loses energy as it moves to a higher energy level
   d) loses energy as it moves to a lower energy level

OBJECTIVE #9: Identifying the Bright Line Spectrum (B.L.S.)

An instrument called a _____, which is basically a prism, can be used to scatter the light emitted electrons within an atom. The pattern that will be seen is then called the _____ _____ spectrum.

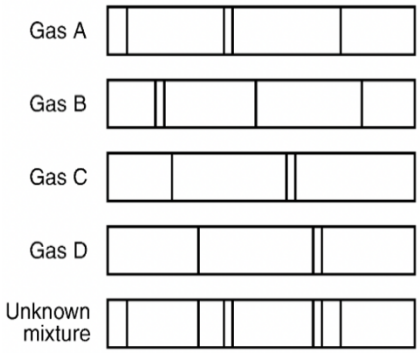
- These patterns of spectral lines are _____ for each element (just like a human fingerprint is unique to each person).

A tremendous amount of research has been done to identify all of the spectral band patterns for each unique element, and a bright line spectrum has been produced for each element.



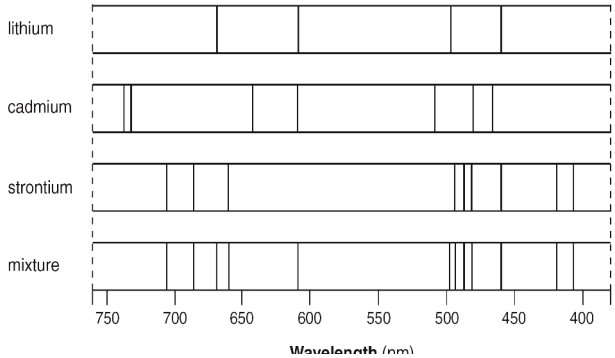
If given an unknown substance, we can use spectral lines to identify which element (or elements) we have (each element gives off its own characteristic bright line spectra.)

1. Identify which two gases (A, B, C, or D) are in the unknown mixture below.



a) Gas A and Gas B
b) Gas A and Gas D
c) Gas B and Gas C
d) Gas B and Gas D

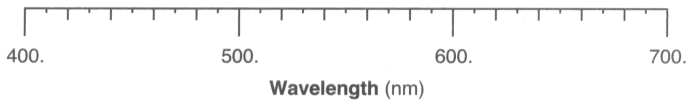
2. Which gases are present in the mixture below?



a) lithium and cadmium
b) cadmium and strontium
c) lithium and strontium
d) lithium, cadmium and strontium

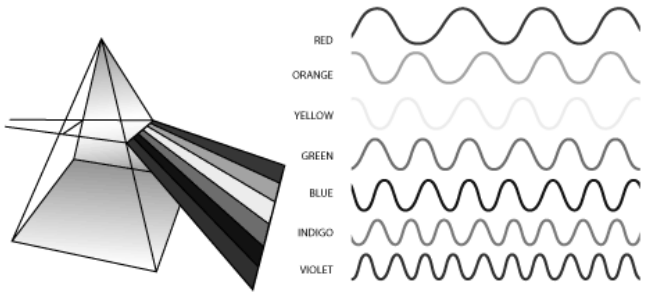
3. The Balmer series refers to the visible bright lines in the spectrum produced by hydrogen atoms. The color and wavelength of each line in this series are given in the table below. Recreate diagram below and draw four vertical lines to represent the Balmer series.

Color	Wavelength (nm)
red	656.3
blue green	486.1
blue	434.1
violet	410.2



OBJECTIVE #10: Calculating the Properties of Visible Light

Visible light waves are the only electromagnetic waves we can see. We see these waves as the colors of the rainbow. Each color has a different wavelength. Red has the _____ wavelength & violet has the _____ wavelength. When all the waves are seen together, they produce white light.

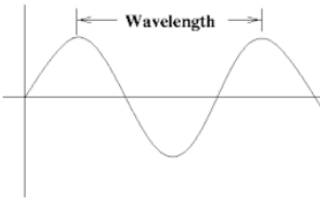


Each color in a rainbow corresponds to a different wavelength of electromagnetic spectrum.

A) Properties of Light Waves

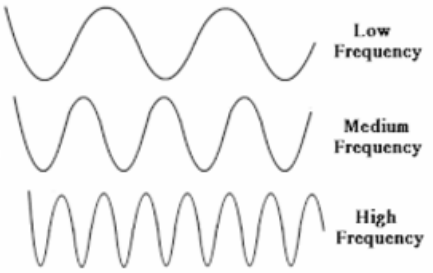
Wavelength (λ) = the _____ between two neighboring peaks

- Units are meters (m) or nanometers (nm)
- 1 nm = 10^{-9} m



Frequency (f) = the number of complete _____ that pass a given point each second

- Unit is $^{1}/_{s}$ or s^{-1}



Energy (E) = the energy a _____ particle possesses in a wave function

- Amount of energy is based on the frequency of the wave and Planck's constant
  - Planck's constant is the physical constant that relates the energy carried by a single photon to its corresponding frequency
- Unit of Energy is in Joules (J)

B) Calculation for Light Waves

Formula 1

Formula 2

Light Calculations

1. Calculate the wavelength of the electromagnetic radiation whose frequency is $7.5 \times 10^{14} s^{-1}$.

2. Determine the frequency of light with a wavelength of 4.257×10^{-7} cm.

3. Determine the energy of a photon whose frequency is $3.55 \times 10^{17}\ s^{-1}$.

4. What is the frequency of a radio wave with an energy of 1.55×10^{-24} J?

5. What is the energy of a photon of ultraviolet light with a wavelength of 4.25×10^{-8} m?

OBJECTIVE #11: Understanding the Quantum (Wave-Mechanical) Model

A) Quantum Model of an Atom
Estimates the probability of finding an electron in certain regions of space called _____ or electron _____.

The location of an atom's electrons in ground state in this model are described by:

A. Principal Energy Level: 1, 2, 3, 4 etc… 7

- the first number describes the MAJOR ENERGY LEVEL of the electron and is called the principle quantum number
- this is the same as the number of the energy level that contains the electrons
    - higher the "n" the more energy

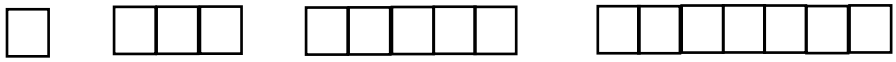
B. Sublevel: s, p, d and f

- Each energy level has one or more sublevels associated with it
    - Each principle energy level contains as many sublevels as the number of the level
      n = 1 has 1 sublevel n = 3 has 3 sublevels
      n = 2 has 2 sublevels n = 4 has 4 sublevels

* Sublevels are described by using the principal energy level together with the letter designation of each sublevel

- 1s - 2s 2p - 3s 3p 3d - 4s 4p 4d 4f

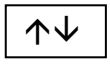
C. Orbitals:



s p d f

- an orbital is a location inside the atom where an electron is most likely to be found
- Orbitals are all the same size; they are represented as boxes  and can fit up to two e- in them

D. Electron Spin: Up ↑ or Down ↓

- This symbol illustrates the distribution of electrons in an atom's sublevel as well as orbital
- Spin is a quantum mechanical property of electrons and may be thought of as up spin or down spin.
    - Up Spin  Down Spin 
    - ** Each orbital can only contain two electrons spinning in the opposite direction due to the fact that electrons are like-charges and repel each other 

Quantum (Wave-Mechanical) Model Summary

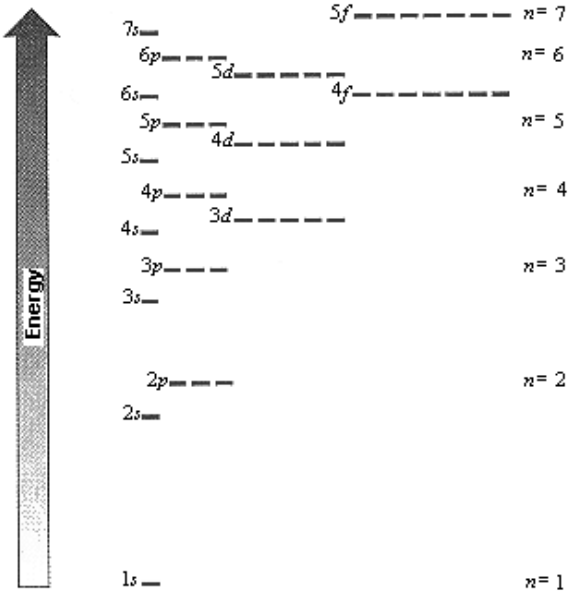
Energy Level	Sublevel(s)	Orbital(s)	# of e-
1			
2			
3			

Three rules when filling sublevels and orbitals:

1) Aufbau principle: electrons enter sublevels (s, p, d and f) and orbitals [ ] of lowest energy first

2) Pauli Exclusion Principle: An atomic orbital can contain a maximum of 2 electrons [↑↓]

3) Hund's rule: When electrons occupy orbitals, one electron enters each orbital with the same spin until all orbitals contain one electron, then pairs can be made with an electron of opposite spin



Writing electron configurations in sublevel (s, p, d, f) and orbital notation [ ]:

Atomic Number	**Bohr Notation**		
3		**Sublevel Notation**	
	Orbital Notation		
8		**Sublevel Notation**	
	Orbital Notation		
11		**Sublevel Notation**	
	Orbital Notation		
17		**Sublevel Notation**	
	Orbital Notation		
20		**Sublevel Notation**	
	Orbital Notation		
*26		**Sublevel Notation**	
	Orbital Notation		

Quantum Model Questions

1. Which phrase describes an atom?
   a) a positively charged electron cloud surrounding a positively charged nucleus
   b) a positively charged electron cloud surrounding a negatively charged nucleus
   c) a negatively charged electron cloud surrounding a positively charged nucleus
   d) a negatively charged electron cloud surrounding a negatively charged nucleus

2. n the wave-mechanical model, an orbital is a region of space in an atom where there is
   a) a high probability of finding an electron
   b) a high probability of finding a neutron
   c) a circular path in which electrons are found
   d) a circular path in which neutrons are found

3. Compared to the energy and charge of the electrons in the first shell of a Be atom, the electrons in the second shell of this atom have
   a) less energy and the same charge
   b) less energy and a different charge
   c) more energy and the same charge
   d) more energy and a different charge

4. The greatest absorption of energy occurs as an electron moves from
   a) 1s to 3s b) 3p to 3s c) 4d to 4s d) 4s to 3p

5. Which of the following sublevels has the highest energy?
   a) 2p b) 2s c) 3p d) 3s

6. An electron in an atom will emit energy when it moves from energy level
   a) 2s to 3p b) 2s to 2p c) 2p to 3s d) 2p to 1s

7. Which electron configuration represents an atom in the excited state?
   a) $1s^2 2s^2 2p^5 3s^1$ b) $1s^2 2s^2 2p^6 3s^1$ c) $1s^2 2s^2 2p^6 3s^2$ d) $1s^2 2s^2 2p^6 3s^2 3p^1$

8. An atom in the excited state can have an electron configuration of
   a) $ls^2 2s^2$ b) $ls^2 2p^1$ c) $ls^2 2s^2 2p^5$ d) $ls^2 2s^2 2p^6$

9. Which is the configuration of an atom in the ground state?
   a) $1s^2 2s^2 2p^6 3s^2$ b) $1s^2 2s^2 2p^6 3p^3$ c) $1s^2 2s^2 2p^5 3s^2$ d) $1s^2 2s^2 2p^5 3p^3$

10. The total number of orbitals in a d sublevel is
   a)1 b) 3 c) 5 d) 7

11. How many occupied sublevels are in an atom of carbon in the ground state?
   a)5 b)6 c)3 d) 4

12. What is the total number of valence electrons in an atom with the electron configuration $1s^2 2s^2 2p^6 3\ s^2 3p^3$?
   a) 3 b) 5 c) 11 d) 15