Chemistry: ***Atomic Structure***

Organization of the Modern Periodic Table

The periodic table is organized by **properties**.

The Atom Today

atom =

All atoms of the same element are essentially (but not exactly) the same.

nucleus =

atomic mass unit =

Parts of the Atom

Particle	Mass	Electrical Charge	Location within the Atom

Particles of the Atom

subatomic particles =

The identity of an atom is determined by how many __________ it has.

atomic number =

Neutrons (James Chadwick, 1932) add mass to the atom.

Why did it take so long to discover the neutron?

mass number =

nucleons =

Electrons are so tiny that we say they have ____ mass, but they have an electrical charge equal in magnitude but opposite to that of the ____________________.

Sample Problem 1: For an atom with 15 protons, 16 neutrons, and 18 electrons…

A) What is the atom's net charge?

B) What is the atomic number of the atom? *What is the mass number?*

C) This is an atom of what element?

Sample Problem 2: For an atom with 28 protons, 31 neutrons, and 26 electrons…

A) What is the atom's net charge?

B) What is the atomic number of the atom? *What is the mass number?*

C) This is an atom of what element?

quarks = smaller particles that make up protons, neutrons, and electrons

The Historical Development of the Atomic Model

Continuous Theory of Matter = the idea that all matter can be divided into smaller and smaller pieces ________________________.

Discontinuous (Particle) Theory of Matter = (~400 B.C., Democritus, Leucippus) matter is made up of particles so small and indestructible that they cannot be divided into anything smaller. "Atom" comes from the Greek word **atomos,** meaning ________________.

law of conservation of mass (1770's, Antoine Lavoisier): provided the first experimental evidence that…

law of definite proportions (Joseph Proust, 1799) the proportion by mass of the elements in a pure compound is always the same

Examples: all samples of water (H_2O) contain a ratio of 8 g oxygen to 1 g hydrogen

all samples of iron sulfide (FeS) contain a ratio of 7 g iron to 4 g sulfur

How does this compare to a physical mixture of iron and sulfur?

law of multiple proportions = when a pair of elements can form 2 or more compounds, the masses of one element that combine with a fixed mass of the other element form simple, whole-number ratios

Example A: 2 compounds of hydrogen and oxygen, H_2O and H_2O_2

$H_2O \rightarrow$

$H_2O_2 \rightarrow$

How does this example show the existence of atoms?

Example B: Sulfur and oxygen can form 2 compounds.

Sulfur dioxide samples show a ratio of 2 g S to 2 g O.

Sulfur trioxide samples show a ratio of 2 g S to 3 g O.

For these two compounds of sulfur and oxygen, what is the small whole-number ratio described by the law of multiple proportions?

Dalton's Atomic Theory (John Dalton, 1803)

1. All elements are made of atoms, which are ____.
2. All atoms of the same element are exactly alike – they have the same mass.
3. Atoms of different elements are different – they have different masses.
4. Compounds are formed by the joining of atoms of 2 or more elements. In any compound, the atoms of the different elements are joined in a definite, whole-number ratio, such as 1:1, 2:1, or 3:2.

Dalton's ideas are still useful today, but modifications to his theory have been made…

William Crookes (1870's): English physicist

Unknowingly , Crookes had discovered _______________. Crookes tubes are now called ________________________________ and are used as _______________________________________.

J.J. Thomson (1897): English scientist

What conclusion did Thomson draw from his observations?

plum pudding model

Using a mass spectrometer, Thomson was able to calculate the **charge to mass ratio ($^e/_m$)**, of an electron.

Robert Millikan determined the charge on an electron in his **oil drop experiment.**

Ernest Rutherford (1906):

Gold Leaf Experiment

What conclusions did Rutherford draw from this evidence?

1.

2.

The tiny central region of the atom was called the **nucleus**, which is Latin for *"________ ______."* Furthermore, Rutherford suggested that the **____________** travel around the **_____________**.

Niels Bohr (1913): Danish physicist. Proposed that electrons can only possess certain amounts of energy, called **quanta**. *What does this mean in terms of the location of electrons?*

Bohr model =

Electron Energy Levels in the Bohr Model

energy levels = the possible electron orbits of an atom

ground state = exists when an atom is energetically stable

excited state = exists when electrons absorb energy, are moved to higher levels, and the atom become energetically unstable

How does an atom give off light?

Charge-Cloud Model, or **Quantum Mechanical Model**

Quantum Mechanics = the idea that **energy is quantized** =

In an atom, where are the electrons, according to the quantum mechanical model?

Summary of the Atomic Model

The atomic model has changed over time, and continues to change as we learn more.

The Nature of Light

Particle versus Waves, 1600's

Sir Issac Newton, English physicist, and the Particle concept of light

Christian Huygens, Dutch physicist, and the Wave concept of light

James Clerk Maxwell, Scottish physicist, (1864) Light as a wave phenomenon

Max Planck, German physicist, revived the particle theory

quanta = discrete bundles of energy that make up light (also called __________________)

The amount of energy in light depends on the __________________ of the light.

Light as Waves: *What is a wave?*

wavelength = the distance between two neighboring peaks or troughs

frequency = the number of peaks that pass a given point each second

Hertz = unit used to express frequency in cycles per second

The Emission and Absorption of Radiation

Studying the light absorbed and emitted by an atom allows us to understand that atom.

electromagnetic radiation = the entire range of "light", from…

very low frequencies (low energy) to very high frequencies (high energy)

VISIBLE
R O Y G B I V

long wavelength
low frequency

short wavelength
high frequency

electromagnetic spectrum =

continuous spectrum = band of colors that results when a narrow beam of light passes through a prism

The **bright line spectrum** of the elements is a unique set of lines for each element.

The Speed of Light and the Energy of Light

Relationship between wavelength, frequency, and speed of light: **$c = \lambda f$**

where **c = the speed of light**

The energy of light is given by the formula **$E = h f$**

Planck's constant, h = the constant of proportionality between the energy and the frequency of radiation

<u>Problem A</u>: *Find the frequency of a quantum of light (a photon) with a wavelength of 6.0×10^{-7} meters.*

<u>Problem B</u>: *Find the energy of a photon of radiation with a frequency of 5.0×10^{14} hertz.*

A Closer Look at Electrons: Where are they in the Atom?

Electrons are located within **energy levels**, which range from **______.** The higher the energy level the electron is in…

1.

2.

sublevels = within each energy level, these differ from each other by slight differences in energy

orbital = "paths" in each sublevel that an electron can travel on.

Each orbital can hold a maximum of ____ electrons.

- In every **s sublevel**, there is ____ orbital, which holds a total of ___ electrons
- In every **p sublevel**, there are ____ orbitals, which hold a total of ___ electrons
- In every **d sublevel**, there are ____ orbitals, which hold a total of ___ electrons
- In every **f sublevel**, there are ____ orbitals, which hold a total of ___ electrons

In what order do orbitals fill up?

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2\ 4f^{14}\ 5d^{10}\ 6p^6\ 7s^2\ 5f^{14}\ 6d^{10}$

Writing the Electron Configuration for an Atom

The question is: Where are the electrons in the atom?

The format for each term in the electron configuration is, for example: **1 s** ^{2}

1 = the energy level s = the sublevel, or orbital 2 = the number of electrons in that sublevel

Examples: *Write the electron configurations for the following elements.*

carbon (C) chlorine (Cl)

lithium (Li) potassium (K)

sodium (Na) iron (Fe)

Using Shorthand Notation for the Electron Configuration

Put the noble gas that precedes the element in brackets, then continue filling the rest of the orbitals in order, as usual.

Examples: sodium (Na) potassium (K)

chlorine (Cl) iron (Fe)

The Significance of the Electron Configurations

valence shell =

valence electrons =

What is the maximum number of valence electrons an atom can have? ______

How do each of the noble gases differ from other atoms?

How do noble gases behave, and why?

Isotopes

Not all atoms of an element are exactly the same in every respect.

How are all atoms of an element alike?

What could be ***different*** *about 2 or more atoms of the same element?*

isotopes =

Example 1: *All carbon atoms have how many protons?*

Most carbon atoms have 6 neutrons. *What is their mass number?*

Some carbon atoms have 8 neutrons. *What is their mass number?*

Example 2: Hydrogen has 3 isotopes, protium (H-1), deuterium (H-2), tritium (H-3).

How many protons, neutrons, and electrons are in a neutral atom of each of the isotopes of hydrogen?

Example 3: *How many neutrons are in a Ag-109 atom?*

isotope notation = used to designate a particular isotope of an element

Isotope Notation	Protons	Neutrons	Electrons
$^{238}_{92}U$			
$^{23}_{11}Na$			
$^{235}_{92}U$			

Average Atomic Mass

Since all atoms of an element do not have the same mass, it is useful to find the average mass of the atoms of an element. *That is, if we took a random sample of a large number of atoms of that element, what would the average mass of those atoms be?*

average atomic mass ("atomic mass") =

The average atomic mass takes into account what percentage of each isotope have a particular mass.

For an element with isotopes "A", "B", etc., the average atomic mass can be found using the equation…

% abundance = tells what percentage of the element's atoms are of each isotope

Example 1: *Complete the following table, assuming that a "Small Atom" has a mass of 12 amu and that a "Large Atom" has a mass of 14 amu.*

Number of "Small Atoms"	Number of "Large Atoms"	% abundance of "Small Atoms"	% abundance of "Large Atoms"	Average Atomic Mass (amu)

Example 2: *Boron has 2 isotopes, B-10 and B-11. The % abundance of B-10 is 19.78%. What is the average atomic mass of boron?*

How do we know the percentage abundance for each isotope of each element?

Unequal Numbers of Protons and Electrons: Ions

In terms of electrons in energy levels, what is special about the noble gases?

How is the overall energy state of noble gases affected by this?

As a result, every atom "wants" to be as much like a noble gas as possible.

Why can't every atom be a noble gas?

How could an element be similar to a noble gas?

Consider the element fluorine, F. A neutral atom of fluorine contains ___ protons and ___ electrons. In order have a full outer energy level (to be like a noble gas, to have low energy and high stability), F has 2 choices…

OPTION 1

OPTION 2

ion =

cation =

anion =

Mnemonics for remembering cations and anions

How does an atom become an anion?

How does an atom become a cation?

Again, an atom **CANNOT** form an ion by gaining or losing protons.

Exercise: Complete the following table.

Element	*Has ? Protons*	*Starts with ? Electrons*	*Wants ? Electrons*	*Gains or Loses ? Electrons*	*Now has ? Electrons*	*Charge on Atom*	*Ion Symbol*
Li							
Na							
Mg							
Ca							
Cl							
Br							
O							

Naming Ions

In naming a cation, we use the form: “name of element” and “ion”

Name the cations in the above table.

In naming an anion, we use the form: “root of element name + -ide” and “ion”

Name the anions in the above table.