John Hanna 7/25-28/19
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ATOMIC STRUCTURE 02

Section A:

Guiding Questions:

- How do we know that atoms exist?
- How do we know that electrons, protons, and neutron exist?
- What is radiation and what does it come from?
- Is radiation safe?
- Where does matter come from?
- How are elements formed?
- Are all atoms of an element the same?
- How do we measure atoms if they are so small?
- How do we know what stars are made of?

A Brief History of Chemistry:

- In the fourth century B.C., ancient Greeks proposed that matter consisted of fundamental particles called atoms.
- Over the next two millennia, major advancements in chemistry were achieved by alchemists. Their major goal was to convert certain elements into others by a process called transmutation.

The Greeks: History of the Atom:

- Not the history of the atom, but the idea of the atom.
- In 400 B.C. the Greeks tried to understand matter (chemicals) and broke them down into earth, wind, fire, and air.
- Democritus and Leucippus were Greek philosophers.

Greek Model:

Democritus:

- Greek philosopher
- Idea of democracy
- Idea of atoms
  - Atomos means invisible
  - Atom is derived
- No experiments to support idea
- Continuous vs. discontinuous theory of matter
- Democritus says, “To understand the very large we must understand the very small.”
- Democritus’s model of an atom is: No protons, electrons or neutrons.
  - Solid and indestructible
- Democritus’s first atomic hypothesis was in 400 B.C.
- Atomos: Greek for “uncuttable”. Chop up a piece of matter until you reach the atomos.

Properties of Atoms:

- Indestructible.
- Changeable, however, into different forms.
- An infinite number of kinds so there are an infinite number of elements.

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- Hard substances have rough, prickly atoms that stick together.
- Liquids have round, smooth atoms that slide over one another.
- Smell is caused by atoms interacting with the nose, rough atoms hurt.
- Sleep is caused by atoms escaping the brain.
- Death is caused by atoms escaping the brain and not returning.
- The heart is the center of anger.
- The brain is the center of thoughts.
- The liver is the seat of desire.
- Nothing exists but atoms and space, all else is opinion.

Four Element Theory:

- Plato was an atomist
- Thought all matter was composed of four elements:
  - Earth (cool, heavy)
  - Water (wet)
  - Fire (hot)
  - Air (light)
  - Ether (close to heaven)

Some Early Ideas on Matter:

- Anaxagoras (Greek born 500 B.C.): Suggested that every substance had its own kind of "seeds" that clustered together to make the substance, much as atoms cluster to make molecules.
- Empedocles (Greek, born in Sicily, 490 B.C.): Suggested that there were only four basic seeds – earth, air, fire, and water. The elementary substance (atoms to us) combined in various ways to make everything.
- Democritus (Thracian, born 470 B.C.): Actually, proposed the word atom (invisible) because he believed that all matter consisted of such tiny units with voids between, an idea quite similar to our own beliefs. It was rejected Aristotle and thus lost for 2000 years.
- Aristotle (Greek, born 384 B.C.): Added the idea of "qualities"- heat, cold, dryness, moisture- as basic elements which combined as shown in the diagram.

Alchemy:

- After that chemistry was ruled by alchemy.
- They believed that that could take any cheap metals and turn them into gold.
- Alchemists were almost like magicians.

Contributions of alchemists:

Information about elements:

- The elements mercury, sulfur, and antimony were discovered.
- Alchemists also defined properties of some elements.
- Alchemists learned how to prepare acids.
- Alchemists developed several alloys.

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- Alchemists developed new glassware.

Early Ideas on Elements:

- Robert Boyle stared: A substance was an element unless it could be broken down to two or more simpler substances. Air therefore could not be an element because it could be broken down in to many pure substances.

Modern Chemistry:

- Beginnings of modern chemistry were seen in the sixteenth and seventeenth centuries, where great advancements were made in metallurgy, the extraction of metals from ores.
- In the seventeenth century, Boyle described the relationship between the pressure and volume of air and defined an element as a substance that cannot be broken down into two or more simpler substances by chemical means.
- During the eighteenth century, Priestley discovered oxygen gas and the process of combustion where carbon-containing materials born vigorously in an oxygen atmosphere.
- In the late eighteenth century, Lavoisier discovered respiration and wrote the first modern chemistry text. His most important contribution was the law of conservation of mass, which states that any chemical reaction, the mass of the substances that react equals the mass of the products that are formed. He is known as the father of modern chemistry.

The Atomic Theory of Matter:

- In 1803, Dalton proposed that elements consist of individual particles called atoms.
- His atomic theory of matter contains four hypotheses:
  - All matter is composed of tiny particles atoms.
  - All atoms of an element are identical in mass and fundamental chemical properties.
  - A chemical compound is a substance that always contains the same atoms in the same ratio.
  - In chemical reactions, atoms from one or more compounds or elements redistribute or rearrange in relation to other to form one or more new compounds. Atoms themselves do not undergo a change of identity in chemical reactions.

Foundations of Atomic Theory:

Law of Conservation of Mass:

- Mass is neither destroyed nor created during ordinary chemical reaction.

Law of Definite Proportions:

- The fact that a chemical compound contains the same elements in exactly the same proportions by mass regardless of the size of the sample or source of the compound.
- Whether synthesized in the laboratory or obtained from various natural sources, copper carbonate always has the same composition.
- Analysis of this compound led Proust to formulate the law of definite proportions.

Law of Multiple Proportions:

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- If two or more different compounds are composed of the same two elements, then the ratio of the masses of the second element combined with a certain mass of the first elements is always a ration of small whole numbers.

Law of Definite Proportions:

- Each compound has a specific ration of elements.
- It is a ratio by mass.
- Water is always 8 grams of oxygen for every one gram of hydrogen.

Law of Multiple Proportions:

- Dalton could not use this theory to determine the elemental compositions of chemical compounds because he had no reliable scale of atomic masses.
- Dalton's data led to a general statement known as the law of multiple proportions.
- Law states that when two elements form a series of compound, the ratios of the masses of the second element that are present per gram of the first element can almost always be expressed as the ratios of integers.
- If two elements form more than one compound, the ratio of the second element that combines with 1 gram of the first element in each is a simple whole number.

Dalton's Atomic Theory:

- Dalton's atomic theory is essentially correct, with four minor modifications
  - Nat all atoms of an element must have precisely the same mass.
  - Atoms of one element can be transformed into another through nuclear reactions.
  - The composition of many solid compounds are somewhat variable.
  - Under certain circumstances, some atoms can be divided (split into similar particles: i.e. nuclear fission).
- Dalton stated that elements consisted of tiny particles called atoms.
- He also called the elements pure substances because all atoms of an element were identical and that in particular, they had the same mass.
  - All matter consists of tiny particles. Dalton, like the Greeks, called these particles "atoms".
  - Atoms of one element can neither be subdivided or changed into atoms of any other element.
  - Atoms can neither be created nor destroyed.
  - All atoms of the same element are identical in mass, size, and other properties.
  - Atoms of one element differ in mass and other properties from atoms of other elements.
  - In compounds, atoms of different elements combine in simple, while number ratios.
- All matter is made of tiny invisible particles called atoms.
- Atoms of the same element are identical, those of different atoms are different.
-

Dalton's Theory Continued:

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- He also said the reason why elements differed from one another was that atoms of each element had different masses.
- He also said that compounds consisted of atoms of different elements combined together.
- Dalton's model was that the atoms were tiny, invisible, indestructible particles and that each one had a certain mass, size and chemical behavior that was determined by what kind of element they were.

History: On the Human Side:

- **1834 Michael Faraday** - electrolysis suggested electrical nature of matter
- **1895 Wilhelm Roentgen** - discovered X-rays when cathode rays strike anode
- **1896 Henri Becquerel** - discovered "uranic rays" and radioactivity
- **1896 Marie (Marya Sklodowska) and Pierre Curie** - discovered that radiation is a property of the atom, and not due to chemical reaction. (Marie named this property radioactivity.)
- **1897 Joseph J. Thomson** - discovered the electron through Crookes tube experiments
- **1898 Marie and Piere Curie** - discovered the radioactive elements polonium and radium
- **1899 Ernest Rutherford** - discovered alpha and beta particles
- **1900 Paul Villard** - discovered gamma rays
- **1903 Ernest Rutherford** and **Frederick Soddy** - established laws of radioactive decay and transformation
- **1910 Frederick Soddy** - proposed the isotope concept to explain the existence of more than one atomic weight of radioelements
- **1911 Ernest Rutherford** - used alpha particles to explore gold foil; discovered the nucleus and the proton; proposed the nuclear theory of the atom
- **1919 Ernest Rutherford** - announced the first artificial transmutation of atoms
- **1932 James Chadwick** - discovered the neutron by alpha particle bombardment of Beryllium
- **1934 Frederick Joliet** and **Irene Joliet Curie** - produced the first artificial radioisotope
- **1938 Otto Hahn, Fritz Strassmann, Lise Meitner,** and **Otto Frisch** - discovered nuclear fission of uranium-235 by neutron bombardment
- **1940 Edwin M McMillan** and **Philip Abelson** - discovered the first trans uranium element neptunium, by neutron irradiation of uranium in a cyclotron
- **1941 Glenn T. Seaborg, Edwin M. McMillan, Joseph W. Kennedy** and **Arthur C. Wahl** - announced discovery of plutonium from beta particle emission of neptunium
- **1942 Enrico Fermi** - produced the first nuclear fission chain-reaction
- **1944 Glenn T. Seaborg** - proposed a new format for the periodic table to show that a new actinide series of 14 elements would fall below and be analogous to the 14 lanthanide-series elements.

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- **1964 Murray Gell-Mann** hypothesized that quarks are the fundamental particles that make up all known subatomic particles except leptons.

Radioactivity (1896):

- Rays or particles produced by unstable nuclei.
  - Alpha Rays-helium nucleus.
  - Beta Part-high speed electron.
  - Gamma ray-high energy x-Ray.
- Discovered by Becquerel-exposed photographic film.
- Further work by Curies
- One of the pieces of evidence for the fact that atoms are made of smaller particles came from Marie Curie (1876-1934).
- She discovered radioactivity, the spontaneous disintegration of some elements into smaller pieces.

Background Information:

Cathode Rays:

- Form when high voltage is applied across electrodes in a partially evacuated tube.
- Originate at the cathode (negative electrode) and move to the anode (positive electrode).
- Carry energy and can do work.
- Travel in straight lines in the absence of an external field.

Conclusions:

- He compared the value with the mass/charge ratio for the lightest charged particle.
- By comparison, Thomson estimated that the cathode ray particle weighed 1/1000 as much as hydrogen, the lightest atom.
- He concluded that atoms do contain subatomic particles particles-atoms are divisible into smaller particles.
- This conclusion contradicted Dalton's postulate and was not widely accepted by fellow physicists and chemists of his day.
- Since any electrode material produces an identical ray, cathode ray particles are present in all types of matter-a universal negatively charged subatomic particle later named the electron.

J.J Thomson:

- He proved that atoms of any element can be made to emit tiny negative particles.
- From this he concluded that all atoms must contain these negative particles.
- He knew that atoms did not have a net negative charge and so there must be balancing the negative charge.

William Thomson (Lord Kelvin):

- In 1910 William Thomson proposed the Plum Pudding model
  - Negative electrons were embedded into a positively charged spherical cloud.

Thomson Model of the Atom:

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- J.J Thomson discovered the electron and knew that electrons could be emitted from matter (1897).
- William Thomson proposed that atoms consist of small, negative electrons embedded in a massive, positive sphere.
- The electrons were like currents in a plum pudding.
- This is called the 'plum pudding' model of the atom.

Other Pieces:

- Protons are positively charged pieces
  - 1840 times heavier than the electron
- Neutrons have no charge but the same mass as a protons.
- How were these pieces discovered?
- Where are the pieces?

Ernest Rutherford (1871-1937):

- Learned physics in J.J. Thomson's lab.
- Noticed that 'alpha' particles were sometimes deflected by something in the air.
- Gold-foil experiment.

Rutherford 'Scattering':

- In 1909 Rutherford undertook a series of experiments.
- He fired alpha particles at a very thin sample of gold foil.
- According to the Thomson model the alpha would only be slightly deflected.
- Rutherford discovered that they were deflected through large angles and could even be reflected straight back to the source.
- Rutherford interpreted this result by suggesting that a particles interacted with very small and heavy particles.

Density and the Atom:

- Since most of the particles went through, the atom was mostly empty.
- Because the alpha Rays were deflected so much, the positive pieces it was striking were heavy.
- Small volume am big mass equals big density
- The small dense positive area is the nucleus.

Modern Atom Model:

- Electrons are in constant motion around the nucleus, protons and neutrons jiggle within the nucleus, and quarks jiggle within the protons and neutrons.
- This picture is quite distorted. If we drew the atom to scale and made protons and neutrons a centimeter in diameter, then the electrons and quarks would be less than the diameter of a hair and the entire atom's diameter would be greater than the length of thirty football fields! 99.999999999999% of an atom's volume is just empty space.

Scale of the Atom:

- While an atom is tiny, the nucleus is ten thousand times smaller than the atom and the quarks and electrons are at least ten thousand times smaller than that. We don't know

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exactly how small quarks and electrons are; they are definitely smaller than 10^{-18} meters, and they might literally be points, but we do not know.

- It is also possible that quarks and electrons are not fundamental after all and will turn out to be made up of other, more fundamental particles.
- Physicists have developed a theory called The Standard Model that explains what the world is and what holds it together. It is a simple and comprehensive theory that explains all the hundreds of particles and complex interactions with only:
- 6 quarks.
- 6 leptons. The best-known lepton is the electron.
- Force carrier particles, like the photon. We will talk about these particles later.
- All the known matter particles are composites of quarks and leptons, and they interact by exchanging force carrier particles.
- The Standard Model is a good theory. Experiments have verified its predictions to incredible precision, and all the particles predicted by this theory have been found. But it does not explain everything. For example, gravity is not included in the Standard Model.

Discovery of the Electron:

- 1807 Davy suggested that electrical forces held compound together.
- 1833 Faraday related atomic mass and the electricity needed to free an element during electrolysis experiments.
- 1891 Stoney proposed that electricity exists in units he called electrons.
- 1897 Thomson first quantitatively measured the properties of electrons.

Coulomb's Law:

- Why don't electrons collide while moving around the outside of atom?
- Both negative charges (repel each other)
- $F = k.q_1.q_2/d^2$
- Why can't we add protons to nucleus?
- Hard to hit small nucleus
- (+) will repel (+)
- When an ion forms:
- cation…gain protons or **lose electrons**?
- anion…lose protons or **gain electrons**?

Evidence for Particles:

- In 1886, Goldstein, using equipment similar to the cathode ray tube, discovered particles with charge equal and opposite to that of electron, but much larger mass.
- Rutherford later (1911) found these particles to be identical to hydrogen atoms minus one electron.
  - Named these particles protons.
- Chadwick (1932) discovered particles with similar mass to protons but zero charge.
  - Discovered neutrons

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Bohr Model of Atom:

- The Bohr model of the atom, like many ideas in the history of science, was at first promoted by and later partially disproved by experimentation.

An Unsatisfactory Model for the Hydrogen Atom:

- According to classic physics, light should be emitted as the electron circles the nucleus. A loss of energy would cause the electron to be drawn closer to the nucleus and eventually spiral into it.

Quantum Mechanical Model:

- Modern atomic theory describes the electronic structure of the atom as the probability of finding electrons within certain regions of space (orbitals).

Modern View:

- The atom is mostly empty space.
- The atom consists of two regions:
  - Nucleus
    - Protons and neutrons
  - Electron cloud
    - Region where you might find an electron.

The Experiment:

- To test this, he designed and experiment directing ‘alpha’ toward a thin metal foil.
  - The foil was coated with a substance that produced flashes when it was hit by an alpha particle.

The Results:

- Most went straight through the foil.
  - Some were deflected at large angles to the sides.
  - Some were even deflected straight backward.

Atomic Review:

- William Thomson’s "plum pudding" model, published in 1904, showed that the model did produce electron arrangements that were stable.
- Thomson’s model was conclusively destroyed by Rutherford's 1911 nucleus paper.
- We know that atoms have a net neutral charge and they have positive and negative parts.

Models of the Atom:

- 1803: John Dalton pictured atoms as tiny, indestructible particles, with no internal structure.
- 1897: J.J. Thomson, a British scientist, discovers the electron, leading to his “plum-pudding” model. He pictures electrons embedded in a sphere of positive electric charge.
- 1904: Hantaro Nagaoka, a Japanese physicist, suggests that an atom has a central nucleus. Electrons move in orbits like the rings around Saturn.
- 1911: New Zealander, Ernest Rutherford states that an atom has a dense, positively charged nucleus. Electrons move randomly in the space around the nucleus.

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- 1913: in Niels Bohr's model, the electrons move in spherical orbits at fixed distances from the nucleus.
- 1924: Frenchman Louis de Broglie proposes that moving particles like electrons have some properties of waves. Within a few years evidence is collected to support his idea.
- 1926: Erwin Schrödinger develops mathematical equations to describe the motion of electrons in atoms. His work lead to the electron cloud model.
- 1932: James Chadwick, a British physicist, confirms the existence of neutrons, which have no charge. Atomic nuclei contain neutrons and positively charged protons.

Thomson's Model:

- In the nineteenth century, Thomson described the atom as a ball of positive charge containing a number of electrons.

Rutherford's Model:

- In the early twentieth century, Rutherford showed that most of an atom's mass is concentrated in a small, positively charged region called the nucleus.

Niels Bohr:

- In the Bohr Model (1913) the neutrons and protons occupy a dense central region called the nucleus, and the electrons orbit the nucleus much like planets orbiting the Sun.
- They are not confined to a planar orbit like the planets are
- Bohr's contributions to the understanding of atomic structure:
  - Electrons can occupy only certain regions of space, called **orbits.**
  - Orbits closer to the nucleus are more stable — they are at lower energy levels.
  - Electrons can move from one orbit to another by absorbing or emitting energy giving rise to characteristic spectra.
- Bohr's model could not explain the spectra of atoms heavier than hydrogen.

Bohr Model:

- After Rutherford's discovery, Neils Bohr proposed that electrons travel in definite orbits around the nucleus.
- **Bohr was able to use his model hydrogen to:**
  - Account for the observed spectral lines.
  - Calculate the radius for hydrogen atoms.
- **His model did not account for:**
  - Atoms other than hydrogen.
  - Why energy was quantized.
- His concept of electrons moving in fixed orbits was later abandoned.

Avogadro's Hypothesis:

- Gay-Lussac attempted to establish the formulas of chemical compounds by measuring, under constant temperature and pressure conditions, the volumes of gases that reacted to make a given chemical compound, together with the volumes of the products if they were gases.

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- Gay-Lussac's results were explained by Avogadro's hypothesis, which proposed that equal volumes of different gases contain equal numbers of gas particles when measured at the same temperature and pressure.

Minor-Major Contributors:

- Lavoisier's (1743-1794)
  - Law of conservation of mass
- Proust's (1754-1826)
  - Law of definite proportions
- Gay-Lussac's (1778-1850)
  - Law of Combining Volumes
- Under constant conditions, the volume of reacting gasses and products are in small who number ratios.
- Avogadro's Principle (1776-1856)Equal volumes of gases, under the same conditions, have the same number of molecules
- Newton (1643-1727) Mechanical universe with small, solid masses in motion (1704)

Particles in the Atom:

- Each element is chemically unique. To understand why they are unique, you need to know the structure of the atom (the smallest particle of an element) and the characteristics of its components.
- Atoms consist of electrons, protons, and neutrons.
  - Electrons and protons have electrical charges that are identical in magnitude but opposite in sign. Relative charges of -1 and +1 and assigned to the electron and proton, respectively.
  - Neutrons have approximately the same mass as protons but no charge—they are electrically neutral.
  - The mass of a proton or a neutron is about 1836 times greater than the mass of an electron. Protons and neutrons constitute the bulk of the mass of the atom.

Discovery of the Neutron:

- James Chadwick bombarded beryllium-9 with alpha particles, carbon-12 atoms were formed, and neutrons were emitted.

Structure of the Atom:

- There are two regions
  - The nucleus
    - With protons and neutrons
- Positive charge
- Almost all the mass

Electron cloud:

- Most of the volume of an atom
- The region where the electron can be found

Size of an Atom:

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- Atoms are incredibly tiny.
- Measured in picometers (10^{-12} meters)
  - Hydrogen atom 32 pm radius
- Nucleus tiny compared to atom
  - Radius of the nucleus near 10^{-15} m.
  - Density near 10^{14} g/cm^3
- If the atom was the size of a stadium, the nucleus would be the size of a marble.

Weighing Atoms:

- Mass spectrometry is used to experimentally determine isotopic masses and abundances.
- Interpreting mass spectra
- Average atomic weights
  - Computed from isotopic masses and abundances
  - Significant figures of tabulated atomic weights gives some idea of natural variation in isotopic abundances.

Atomic Mass:

- How heavy is an atom of oxygen?
- There are different kinds of oxygen atoms.
- More concerned with average atomic mass.
- Based on abundance of each element in nature.
- Don't use grams because the numbers would be too small

Measuring Atomic Mass:

- Unit is the Atomic Mass Unit (amu)
- One twelfth the mass of a carbon-12 atom.
- Each isotope has its own atomic mass we need the average from percent abundance.

Calculating Averages:

- You have five rocks, four with a mass of 50 g, and one with a mass of 60 g. What is the average mass of the rocks?
- Total mass = (4 x 50) + (1 x 60) = 260 g
- Average mass = (4 x 50) + (1 x 60)/5 = 260 g/5
- Average mass = 4 x 50/5 + 1 x 60/5 = 260 g/5

Isotopes:

- Because of the existence of isotopes, the mass of a collection of atoms has an average value.
- Average mass = ATOMIC WEIGHT
- Boron is 20% B-10 and 80% B-11. That is, B-11 is 80 percent abundant on earth.
- For boron atomic weight
  = 0.20 (10 amu) + 0.80 (11 amu) = 10.8 amu
- Given the average atomic mass of an element is 118.21 amu and it has three isotopes ("A", "B", and "C"):
  - isotope "A" has a mass of 117.93 amu and is 87.14% abundant

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  - isotope "B" has a mass of 120.12 amu and is 12.36% abundant

Find the mass of isotope "C".
Show work for credit.

Periodic Table:

- Dmitri Mendeleev developed the modern periodic table.
- Argued that element properties are periodic functions of their atomic weights.
- We now know that element properties are functions of ATOMIC NUMBERS.

Quantum Model of the Atom:

Waves and Particles:

De Borglie's Hypothesis:

- Particles have wave characteristics.
- Waves have particle characteristics.
- L=h/mv
- Wave-Particle Duality of Nature.
- Waves properties are significant at small momentum.

Electron as Waves:

- Louis de Borglie (1924)
- Applied wave-particle theory to electrons
- Electrons exhibit wave properties

Quantum Mechanics:

- Heisenberg Uncertainty Principle:
  - Impossible to know both the velocity and position of an electron at the same time.
  - In order to observe an electron, one would need to hit it with photons having a very short wavelength.
  - Short wavelength photons would have a high frequency and a great deal of energy.
  - If one were to hit an electron, it would cause the motion and the speed of the electron to change.
  - Lower energy photos would have a smaller effect but would not give precise information.

The Electron as a Wave:

- Schrödinger's wave equation:
  - Used to determine the probability of finding the H electron at any given distance from the nucleus.
  - Electron best described as a cloud
    - Effectively covers all points at the same time (fan blades)

Quantum Numbers:

- Used the wave equation to represent different energy states of the electrons
- Set of four numbers to represent the location of the outermost electron

The Principal Quantum Number:

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- The quantum number n is the principal quantum number.
  - The principal quantum number tells the average relative distance distances of the electron from the nucleus.
  - N=1,2,3,4...
  - As n increases for a given atom, so does the average distances of the electrons form the nucleus.
  - All wave functions that have the same values of n are said to constitute the principle shell because those electrons have similar average distances from the nucleus.

The Azimuthal Quantum Number:

- Second quantum number l is called the azimuthal quantum number.
- Value of l describes the shape of the region of space occupied by the electron.
- Allowed values of l depend on the value of n and can range from 0 to n – 1.
- All wave functions that have the same value of both n and l form a subshell.
- Regions of space occupied by electrons in the same subshell have the same shape but are oriented differently in space.

A Cross Section of an Atom:

- The first ionization energy level has only one sublevel (1s). The second energy level has two sublevels (2s and 2p). The third energy level has three sublevels (3s, 3p, and 3d).
- Although the diagram suggests that electrons travel in circular orbits, this is a simplification and is not actually the case.

The Magnetic Quantum Number:

- Third quantum is m_l, the magnetic quantum number
- Value of m_l describes the orientation of the region in space occupied by the electrons with respect to an applied magnetic field
- Allowed values of m_l depend on the value of l

m_l can range from –l to l in integral steps

$$m_l = -l, -l + 1, \ldots 0 \ldots, l - 1, l$$

- Each wave function with an allowed combination of n, l, and m_l values describes an atomic orbital, a particular spatial distribution for an electron
- For a given set of quantum numbers, each principal shell contains a fixed number of subshells, and each subshell contains a fixed number of orbitals.

Electron Spin: The Fourth Quantum Number:

- When an electrically charged object spins, it produces a magnetic moment parallel to the axis of rotation and behaves like a magnet.
- A magnetic moment is called electron spin.
- An electron has two possible orientations in an external magnetic field, which are described by a fourth quantum number m_s.
- For any electron m_s can have only two possible values, designated + (up) and – (down) indictating that two oreientations are opposite and subscript s is for spin.

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- An electron behaves like a magnet that has one of two possible orientations, aligned either with the magnetic field or against it.

Electron Configuration

Filling Rules for Electron Orbitals:

- Aufbau Principles: Electrons are added one at a tine to the lowest energy orbitals available until all the electrons of the atom have been accounted for.
- Pauli Exclusion Principle: An orbital can hold a maximum of two electrons. To occupy the same orbital, to electrons must spin in opposite directions.
- Hund's Rule: Rlrctrons occupy equal-energy orbitsld so that a maximum number of unpaired electrons results.

Spin Quantum Number, m_s:

- The electrons behaves as if it were spinning about an axis through its center. The electron spin generates a magnetic field, the direction of which depends on the direction of the spin.

Distrubutiion of Electrons:

- Aufbau Principle: Electrons occupy the positions of the lowests energy.
- Hunds Rule: Electrons in the same sublevel occupy empty orbitals rather than pair up.
- Pauli Exclusion Principle: No two electrons in an atom have the same four quantum number's.

Stabitity:

Ion Formation:

- Atoms gain or lose electrons to become more stable.
- Isoelectronic with the Noble Gases.

Isaac Newton 1642-1727):

- One of the last well known alchemists was the English scientist Isaac Newton.
- In addition to studying more legitimate sciences such as physics and math, Newton spent much of his time on alchemy. Indeed it has been said that Newton was not the "first of the age of reason but that he was the last of the magicians."

Symbols for Elements:

- We use abbreviations to make our lives easier.
- The symbols normally consist of the first letter or first two letters of the element name.
    - The first letter is always capitalized.