HISTORY OF THE ATOM

Atoms are the fundamental unit of elements. They are the smallest particle that retains the chemical identity of the element. You could say that atoms of the same element are the same, atoms of different elements are different. The atomic model has developed slowly over time through the discoveries of various scientists.

In 1803, a British school teacher, **John Dalton** expressed that matter could be explained in terms of atoms. Dalton proposed an "Atomic Theory of Matter".

Dalton's Atomic Theory of Matter

1. Each element is composed of extremely small particles called **atoms**.
2. All atoms of a given element are identical, but they differ from those of any other element.
3. Atoms are neither created or destroyed in any chemical reaction.
4. A given compound always has the same relative number and kinds of atoms.
   (Law of Constant Composition – A given compound always retains the same elements in the same proportions by mass.)

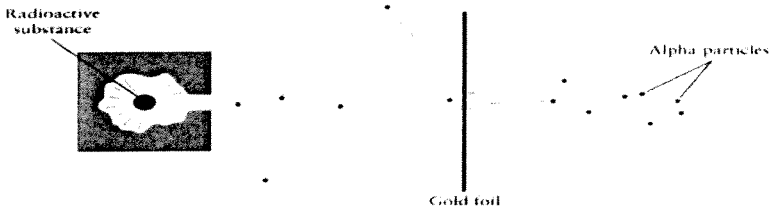
Dalton's theory was a great starting place but we have since learned that many of his postulates are incorrect:

1. Atoms have subatomic particles.
2. Elemental atoms differ: isotopes.
3. Atoms can change from one element to another during nuclear reactions.

Faraday is credited with proposing that atoms contained particles that have electrical charge. **J. J. Thompson** used his studies with cathode rays to prove the existence of charged subatomic particles. A cathode tube creates a cathode ray that is emitted from a negatively charged electrode (cathode) and travels to the positively charged electrode (anode). Thompson found that the stream could move a paddle wheel and could also be deflected by a magnet. Thompson named the negatively charged particles electrons.

Millikan discovered that electrons are extremely light particles. He charged oil droplets and allowed them to fall between charged plates, through this experiment he found that electrons are 2000 times lighter than an atom of hydrogen. (A hydrogen atom contains 1 neutron, 1 proton and 1 electron.

Rutherford studied radioactive materials: alpha (α) particles which have a 2+ charge, beta (β) particles which are high speed electrons and gamma (δ) radiation which is similar to x-rays and is not composed of particles. From his information Rutherford deduced that atoms were more complex than Dalton had thought. Rutherford used a stream of α particles and focused them on a thin piece of gold foil. (See illustration on next page.) He found that most of the particles passed through, however, some of the particles were deflected. From this he deduced that the atom must be made up of mostly space with a tight *nucleus* that has a positive charge, with electrons orbiting it as if it were a miniature solar system.



Bohr felt that Rutherford's model of an atom did not explain why an atom is stable. Bohr proposed that the electrons were in different energy levels orbiting at different levels from the nucleus. When an electron is at its lowest energy it is in the lowest energy level (orbit) – **ground state**. At times electrons can be given additional energy, when this happens electrons will jump to higher energy levels – **excited state**. When an atom is in the excited state it is unstable, it will not remain excited. It will eventually *emit* this energy and return to its ground state. Energy levels are numbered 1,2,3... and correspond to shells *k, l, m*...

ATOMIC STRUCTURE

Atoms are made up of protons, neutrons and electrons; it is now believed that there are additional particles inside these particles called quarks, gluons, mesons, muons and the list goes on. It has also been found that electrons do not have a defined orbit but are in an electron cloud.

Electrons carry a negative charge, as proved by Thompson, and protons carry a positive charge. However, the proton is not the only particle found in Rutherford's positive nucleus, neutrons are located in the nucleus also but are neutral. An individual atom is neutral; the number of protons and electrons are the same. The number of protons in an atom is denoted by the **atomic number**. The **atomic weight** is the average weight of all naturally occurring isotopes. Weight and mass are expressed in **atomic mass units** which is an arbitrary standard based on carbon-12; 1 amu = 1/12 the mass of a carbon-12 atom = 1.66×10^{-24}g. The **atomic mass** is the number of protons and neutrons (the atomic weight rounded to the nearest whole number.) Although the mass of a neutron is slightly larger than that of the proton we often round them both to 1 amu (atomic mass unit) and the electron to 0 amu.

Complete the following PNE chart using your knowledge of atomic structure and the periodic table.

Complete the following chart.

Element	Symbol	Atomic Number	Mass Number	No. of Protons	No. of Electrons	No. of Neutrons
Oxygen			**16**		**8**	
	Na	**11**				**12**
		14		**14**		**14**
Hydrogen		**1**	**1**	**1**		
		7		7		7

An **ion** is an atom that has lost or gained electrons. We describe ions based on the new net charge created by the change in electrons; for example when oxygen gains 2 additional electrons we now call it O^{2-}. This can be determined by the formula: charge = number of protons – number of electrons

Isotopes are atoms of the same element that have different numbers of neutrons. We describe ions using both the atomic weight and the number of neutrons. For carbon-12 we would write $^{12}_{6}C$ indicating that element 6 has 12 neutrons. For carbon-13 we would write $^{13}_{6}C$.

Complete the following chart based on your knowledge of atoms, ions and isotopes.

Isotope	Symbol	Atomic Number	Mass Number	Number of Neutrons
Aluminum-28				**15**
	$^{14}_{6}C$			
Chlorine-37		**17**		

To determine the average atomic mass of an element percent of each of its various isotopes need to be taken into account.

The formula for calculating ave. atomic mass = $\frac{(\text{mass}_a \times \%_a) + (\text{mass}_b \times \%_b) + (\text{mass}_c \times \%_c) + \ldots}{100}$

Calculate the ave. atomic mass of the isotopes of carbon: carbon-12 98.9% and carbon-13 1.1%

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Homework: Atoms – History and Models

Completion: Fill in each blank with a completed term or short answer.

1. Atoms of each element are _____ from the atoms of all other elements.

2. The law of _____ states that a given compound always retains the same elements in the same proportions by mass.

3. Which scientist theorized that the atom was indivisible? _____

4. Electrons have a _____ charge, protons have a _____ charge, and neutrons are _____.

5. Which to particles are found in the nucleus? _____ and _____

6. The atom's nucleus was discovered by _____ and his gold foil experiement.

7. Dalton was incorrect when he said that all atoms of the same element are the same. We know that atoms of the same element can be different. When the atoms have different amounts of electrons they are called _____.

8. When atoms of the same element have different numbers of neutrons they are called _____.

9. The number of _____ in the nucleus of the atom is the atomic _____ for that element.

10. The number of _____ and _____ must be equal for an atom to be neutral.

11. Thompson discovered the negatively charged particles and named them _____

12. What does "amu" stand for? _____ _____ _____

13. _____ proposed that electrons actually exist in discrete energy levels.

14. The lowest energy level that an electron can exist in is called _____ _____.

15. When an electron drops from the excited state energy is _____.

16. List the relative masses of the electron, proton and neutron.
    Electron = ____ amu Proton = ____ amu Neutron = ____ amu

17. The _____ _____ of an element is the weighted average of the masses of the isotopes of that element.

18. For the isotope $^{54}_{24}Cr$ the 24 represents the _____ and 54 represents the _____

19. _____ _____ is the atomic weight rounded to the nearest whole number.

20. The number of neutrons in the nucleus can be determined by subtracting the _____ from the atomic mass.

Complete the following chart.

Element	Symbol	Atomic Number	Mass Number	No. of Protons	No. of Electrons	No. of Neutrons
Carbon			**12**		**6**	
	K	**19**				**21**
		12		**12**		**12**
Helium		**2**	**4**	**2**		
		5		**5**		**6**

Complete the following chart.

Isotope	Symbol	Atomic Number	Mass Number	Number of Neutrons
Nitrogen-15				**8**
	$^{22}_{10}Ne$			
Beryllium-9		**4**		

Calculate the average atomic weight for each of the following.

1. $^{54}_{24}Cr$ 2.36%

   $^{53}_{24}Cr$ 9.50%

   $^{52}_{24}Cr$ 83.79%

   $^{50}_{24}Cr$ 4.35%

2. $^{20}_{10}Ne$ 90.51%

   $^{21}_{10}Ne$ 0.27%

   $^{22}_{10}Ne$ 9.22%

TYPES OF ATOMIC REACTIONS

Most atomic reactions involve electrons and are referred to as chemical reactions. Chemical bonds generally indicate the transfer or sharing of electrons. Some reactions, however, involve changes in the atom's nucleus. These reactions are called nuclear reactions. Nuclear reactions may include changes in the number of neutrons and/or protons present. Most nuclear reactions are radioactive. Radioactivity is the spontaneous emission of radiation from an atom.

The nucleus of an atom is composed of neutrons and protons in a very compact area. The protons all carry a positive charge and therefore repel each other, but some force holds them all together. Scientists call this force **strong nuclear force**. Neutrons add strong nuclear force to a nucleus, which helps keep the electrical force among the protons from breaking the nucleus apart. Neutrons act like nuclear glue. Elements 1-20 have equal numbers of neutrons and protons and are stable. After 20 a nucleus requires more neutrons to remain stable. After element 83, there is no number of neutrons that will make an element stable, therefore all elements after 83 are radioactive. Too many neutrons can also make the nucleus unstable.

When a nucleus begins to break down radiation is released. This is called radioactive decay. During this process a new nucleus is formed. If the number of protons present changes a new element is formed.

Types of Radiation

Name	Identity	Charge	Penetration Ability	Written As:
Alpha (α)	Helium-4-nuclei	2+	Low, stopped by paper	$^{4}_{2}He^{2+}$, $^{4}_{2}He$, or $^{4}_{2}\alpha$
Beta (β)	Electrons	1-	Medium, stopped by clothing	$^{0}_{-1}e$, $^{0}_{1}e$, or $^{0}_{-1}\beta$
Gamma (δ)	High energy, non-particle	None	Stopped by lead	

Beta radiation is high speed electrons that are not electrons from the atom (outside electrons). A change in the nucleus occurs when the high speed electrons bump into a neutron. When a collision occurs a neutron changes into a proton and an electron. The proton remains in the nucleus propelling the electron out. This type of radiation is 100x more penetrating than alpha radiation.

Gamma rays accompany alpha and beta radiation, gamma rays are much more penetrating and are stopped by lead and concrete.

Other types of nuclear reactions include nuclear fusion and nuclear fission. Nuclear fusion occurs in the sun. In nuclear fusion hydrogen atoms collide forming a helium nucleus. This collision releases a great amount of energy. Nuclear fission is the splitting of a nucleus.

We use nuclear equations to keep track of the reaction's components.

- For example:
  Write the nuclear equation for the alpha decay of radium-226
  $^{226}_{88}Ra \longrightarrow {}^{222}_{86}Rn + {}^{4}_{2}\alpha$

- Write the nuclear equation for the beta decay of iodine-131
  $^{131}_{53}I \longrightarrow {}^{131}_{54}Xe + {}^{0}_{-1}\beta$

Practice: Write a nuclear equation for the following reactions.

1. alpha decay of plutonium-242

2. alpha decay of protactinium-231

3. beta decay of francium-223

ATOMIC STRUCTURE AND THE PERIODIC TABLE

The atomic number is equal to the number of protons in the atom.
The group the atom is located in tells the number of valence electrons present.
The period the atom is located in tells the number of energy levels present.

If you were to look at the number of elements listed on the 1st period of the periodic table, and remembering that this row represents energy level one, how many electrons may exist in energy level one? _____

If you were to look at the number of elements listed on the 2nd period of the periodic table, and remembering that this row represents energy level one, how many electrons may exist in energy level two? _____

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Homework: Types of Atomic Reactions

Fill in the blanks for the following questions.

1. Chemical reactions are reactions that involve _____.

2. Nuclear reactions are reactions that involve _____ and/or _____.

3. Neutrons act like nuclear _____ and keep the protons from _____ each other.

4. The force that holds a nucleus together is referred to as _____ _____ _____.

5. After element 83 there are no number of neutrons that can make the atoms stable and therefore these elements are _____.

6. The decay that results in the atom losing 2 protons is called _____ _____ and written as _____.

7. The decay that results in an neutron breaking down into a proton and an electron is called _____ _____ and is written as _____.

8. The type of radiation in question 7 is caused by _____ _____ _____.

9. _____ is the spontaneous emission of radiation from an atom.

10. The most penetrating type of radiation is _____ _____.

True or False: If the statement is true write True. If it is false, write the correct term.

_____ 1. Radioactivity results from changes in the atom's <u>nucleus</u>.

_____ 2. <u>Gamma</u> radiation consists of particles with a 2+ charge.

_____ 3. When a high speed electron collides with a nucleus a neutron is <u>released</u>.

_____ 4. During alpha decay the number of <u>neutrons</u> present decreases by two.

_____ 5. Nuclear fusion and nuclear fission are also types of <u>nuclear reactions</u>.

Write a nuclear equation for the following reactions.

1. the alpha decay of gold-185

2. the alpha decay of uranium-238

3. the alpha decay of astatine-213

4. the beta decay of sodium-24

5. the beta decay of carbon-14

6. the beta decay of titanium-50

For the following elements describe their structure based on your knowledge of the atom and of the periodic table.

Element	# of Protons	# of Electrons	Total # of energy levels	# of electrons in energy level 1	# of electrons in energy level 2	# of electrons in energy level 3
Hydrogen						
Neon						
Silicon						
Argon						