Name: ______________________________

Block ______________

Unit 3- The Atom

Major Objectives: At the end of this unit, you should be able to:

1. Identify the types of radioactive decay.
2. Identify nuclear transformation processes.
3. Identify radiation detection instruments.
4. Determine the half-life of an element.
5. Differentiate between fusion and fission processes.
6. Write balanced nuclear equations.

Notes

DEMOCRITUS

1. Was Democritus a scientist? __________
2. In what time of history did he live? _______________
3. Describe Democritus' thoughts about gold.
4. What was Democritus' word for something that cannot be cut? _______________

DALTON

1. When did Dalton publish his atomic theory? _______
2. What were Dalton's 6 points?

   a)____

   b)____

   c)____

   d)____

   e)____

   f)____

THOMSON

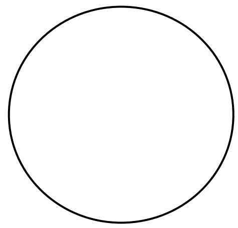
1. What is a cathode ray tube? ______________________________

2. What does a cathode ray consist of? ______________________________

3. How did Thomson know that the particles were negative? ______________

____

4. Draw the plum pudding model of the atom and label the positive charge and the electrons.



RUTHERFORD

1. Describe the Rutherford gold foil experiment.

2. What charge do alpha particles have? ________

3. What did Rutherford think was *supposed* to happen when the alpha particles hit the gold foil?

____

4. What was the surprising result that occurred?

____

5. What did Rutherford think was the reason why a few alpha particles bounced backwards?

____

6. Draw the model of the atom according to Rutherford. Label the nucleus and label the electron cloud.

James Chadwick

1. What did Chadwick discover?

2. How did this change our model of the atom?

3. Explain what makes up the mass of the atomic nucleus.

Niels Bohr

1. Niels Bohr proposed the Bohr Model of the Atom ________________.

2. The Bohr Model has an atom consisting of a small, _______________________ orbited __________________________________.

3. Because the Bohr Model is a modification of the earlier _________________, some people call Bohr's Model the _____________________________.

4. The modern model of the atom is based on ________________________________.

5. The Bohr Model is a _____________________________ in which the negatively-charged electrons orbit a small, positively-charged nucleus similar to the planets orbiting the Sun (except that the ____).

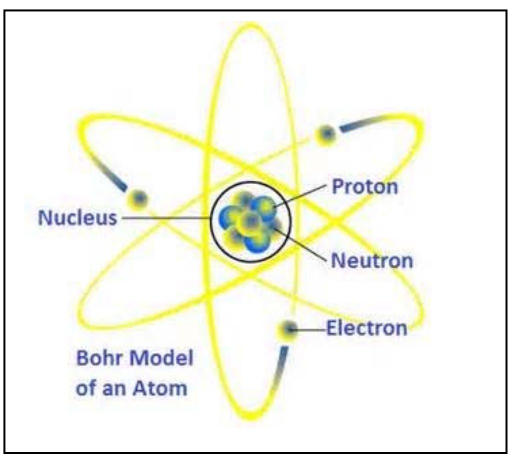
Main Points of the Bohr Model

a)____

b)____

c)____

The Bohr Model



Atomic Models Summary Table

Name	Characteristics	Picture
Dalton (marble model)	Electrons: Protons: Neutrons: Other:	
Thomson (plum pudding model)	Electrons: Protons: Neutrons: Other:	
Rutherford (planetary model)	Electrons: Protons: Neutrons: Other:	
Bohr (quantum model)	Electrons: Protons: Neutrons: Other:	

Important Scientists in the Atomic Theories and Models

-*atomos*, initial idea of atom – Democritus
- first atomic theory of matter, solid sphere model – John Dalton
- discovery of the electron using the cathode ray tube experiment, plum pudding model – J. J. Thomson
- discovery of the nucleus using the gold foil experiment, nuclear model – Ernest Rutherford
- discovery of charge of electron using the oil drop experiment – Robert Millikan
- energy levels, planetary model – Niels Bohr
- periodic table arranged by atomic mass – Dmitri Mendeleev
- periodic table arranged by atomic number – Henry Moseley
- quantum nature of energy – Max Planck
- uncertainty principle, quantum mechanical model – Werner Heisenberg
- wave theory, quantum mechanical model – Louis de Broglie.

DEVELOPMENT OF THE ATOMIC THEORY
From 1000 B.C. to now

DATE	**INFORMATION**
1000 B.C.	Man used metals to create weapons and jewelry. Egyptians found chemicals to embalm bodies.
400 B.C.	Greeks began to explain why chemicals changes occurred. They developed the idea of four elements: fire, earth, water, and air. Greeks also tried to figure out if matter could be broken down. Democritus created the name *atomos* (atoms) to describe these smaller particles.
next 2000 years	Alchemists, also known as fake chemists tried to turn cheap materials into gold. They discovered mercury, sulfur, antimony and how to prepare acids.
	Georg Bauer and Paracelsus expanded the development
17th century	Robert Boyle (1627-1691) examined the relationship between pressure and volume of a gas. He published a book *The Sceptical Chemist* that allowed physics and chemistry. He also looked upon chemicals as only being an element when it could no longer be broken down.
18th century	Georg Stahl (1660-1734) from Germany began investigating the phenomenon of combustion. He believed that a substance called phlogiston was the substance used to burn things and when it became too saturated in a closed container, the fire would stop burning.
	Joseph Priestley (1733-1804) discovered oxygen and found to support combustion. He also found carbon dioxide in a fermentation of grain
	Fundamental Chemical Laws
	Antoine Lavoisier (1743-1794) described the true reason for combustion. He was very careful when measuring his experimental work and found the *Law of Conservation of Mass.* This law states that mass is neither lost or created in an experiment. He published the first chemistry book *Elementary Treatise on Chemistry*.
19th century	Joseph Proust (1754-1826) was a Frenchman that discovered a given compound always contains exactly the same proportions of the elements by weight. This law started being called Proust's Law and is now named the *Law of definite Proportion.*
	John Dalton (1766-1844) found the *Law of Multiple Proportions* that described compounds. This law stated that two elements form a series of compounds, the ratios of the masses of the second element that combine with 1gram of the first can always be reduced to a small whole number. This discovery on carbon and oxygen lead to looking deeper into the idea that atoms existed and to finding exact compositions

The Atom- Notes

- ____________________________________ determine(s) the reactivity of the atom.
- ____________________________________ determine(s) the stability of the atom.
- ____________________________________ determine(s) the identity of the atom.
- Atoms with different numbers of NEUTRONS are called ___________________________.
- The number of PROTONS is represented by the ______________________________.
- The number of NEUTRONS and PROTONS is represented by the ________________________.
- Standard nuclear notation is used to represent each isotope in existence.

$$^{A}_{Z}X$$

- Write the symbol for the atom that has an atomic number of 9 and a mass number of 19. How many protons, neutrons and electrons does this atom have?
- How many protons, neutrons and electrons does this atom have?
    - Oxygen- 16
    - Hydrogen-2
    - Carbon-13

Average Atomic Mass- Notes

- The mass of each element is a ______________________________________ of the isotopes in the element.
- Example 1:
  Silicon has three stable isotopes. The following information is available for the three isotopes:

Isotope	Mass (amu)	Fractional Abundance (%)
Silicon - 28	27.977	92.21
Silicon - 29	28.976	4.70
Silicon - 30	29.974	3.09

- Example 2:
  Iron has four stable isotopes. The following information is available for the four isotopes:

Isotope	Mass (amu)	Fractional Abundance (%)
Iron - 54	53.9396127	5.845
Iron - 56	55.9349393	91.754
Iron - 57	56.9353958	2.119
Iron - 58	57.9332773	0.282

Average Atomic Mass Worksheet

Calculate the average atomic mass for the following elements. Show ALL work!

1. Naturally occurring chlorine is 75.78% ^{35}Cl, which has a mass of 34.969 amu and 24.22% ^{37}Cl, which has a mass of 36.966 amu. Calculate the average atomic mass of chlorine.

2. Three isotopes of silicon occur in nature: ^{28}Si (92.23%), which has a mass of 27.97693 amu; ^{29}Si (4.68%), which has a mass of 28.97649 amu; and ^{30}Si (3.09%), which has a mass of 29.97377 amu. Calculate the atomic mass of silicon.

3. The element lead consists of four naturally occurring isotopes with masses 203.97302, 205.97444, 206.97587 and 207.97663 amu. The relative abundances of these four isotopes are 1.4, 24.1, 22.1 and 52.4% respectively. From these data, calculate the average atomic mass of lead.

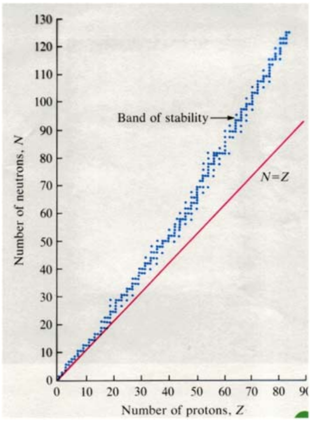
4. An unidentified element was found to have two naturally occurring isotopes. The first isotope labeled ^{85}X has a mass of 84.9117 amu (72.15%) and the second isotope labeled ^{87}X has a mass of 86.9085 amu (27.85%). Calculate the atomic mass of the element and identify the element.

5. The atomic weight of gallium is 69.72 amu. The masses of the naturally occurring isotopes are 68.9257 amu and 70.908 amu for ^{69}Ga and ^{71}Ga respectively. Calculate the % abundance of each isotope.

Nuclear Decay- Notes

- The stability of a nucleus is dependent on the ratio of neutrons to protons (N:Z).
- For light nuclei (atomic number of 20 and less), the N:Z ratio should be 1:1.
- For heavy nuclei (above 20), the N:Z ratio should be 1.5:1.

Band of Stability



- Atoms that lie either above or below the band of stability will undergo nuclear decay to achieve stability.
- Atoms that lie ABOVE the band of stability have ________

  ____.

- Atoms that lie BELOW the band of stability have _______

  ____.

Beta Decay:

- Atoms that lie above the band of stability will undergo beta decay.

- The source of the beta particle is a neutron. Beta decay will increase the number of protons.

- Beta Decay of Carbon-14:

Alpha Decay:

- Atoms with more than 83 protons will decay automatically. The number of neutrons and protons need to be reduced. An alpha particle is the same as the nucleus of a helium atom.

- Alpha Decay of Polonium-210:

Positron Emission:

- Isotopes that lie blow the band of stability will undergo positron emission.

- The source of a positron is a proton. The number of protons will decrease.

- Positron Emission of Carbon-11:

Electron Capture:

- Isotopes that lie below the band of stability can undergo electron capture.

- A proton incorporates an inner shell electron and forms a neutron. This will decrease the number of protons.

- Electron Capture of Aluminum-26:

Gamma Radiation:

- A release of energy, no change in mass occurs.
- There is no charge.
- Gamma rays are assumed to be released in all forms of decay.

Radiation Type	Particle	Mass	Charge	Change in Mass #	Change in Atomic #
Alpha Decay					
Beta Decay					
Positron Emission					
Electron Capture					
Gamma Radiation					

Radioactive Decay

Write the reaction that represents the following:

1. Alpha decay of Polonium – 218.

2. Electron capture of Promethium – 142.

3. Beta decay of Potassium – 43.

4. Alpha decay of Uranium – 233.

5. Beta decay of Nitrogen – 13.

6. Positron emission of Carbon – 14.

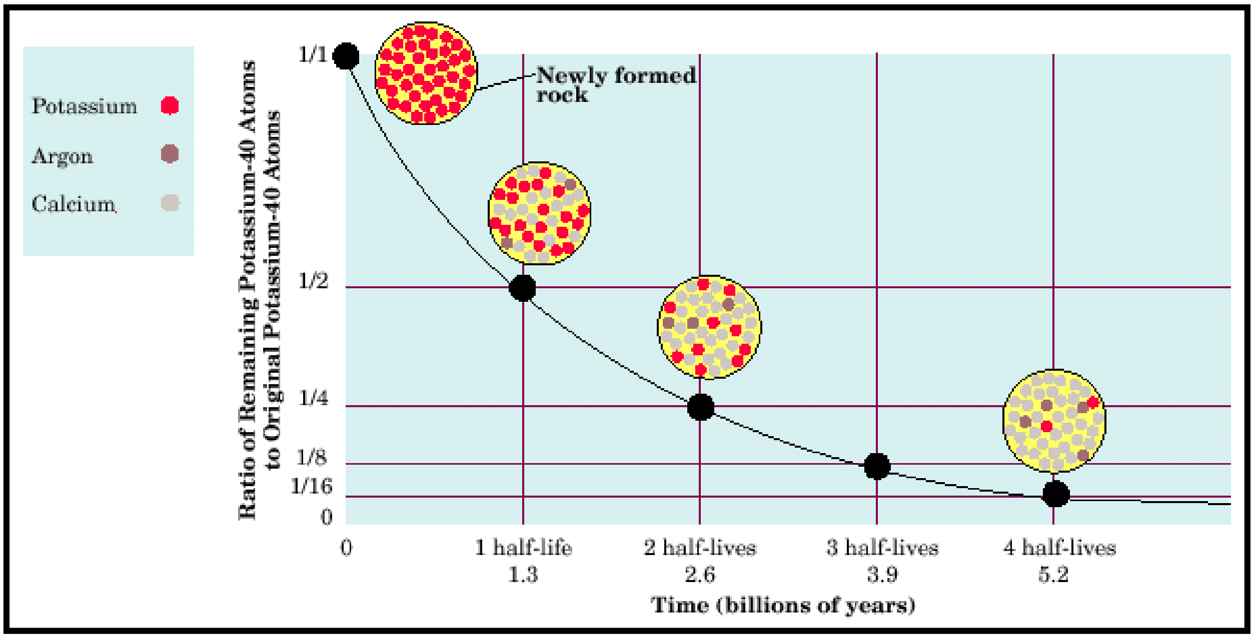
7. Alpha decay of astatine – 196.

8. Electron capture of mercury – 201.

9. Alpha decay of Radon – 226.

10. Beta decay of Iodine – 136.

Half-life Notes



Formula for calculating half-lives:

m_f:
m_o:
t:
$t_{1/2}$:
n:

<u>Example</u>: Fluorine-21 has a half-life of 5.0 seconds. If you start with 25 g of fluorine-21, how many grams would remain after 60.0 s?

Given:	Work:

Nuclear Chemistry – Half-Life

Complete the following half-life problems. Show ALL work.

1. The half-life of plutonium – 239 is 24,100 years. Of an original mass of 100. g, how much remains after 96,440 years?

2. The half-life of Thorium – 227 is 18.72 days. How many days are required for 1/8 of a given amount to remain?

3. Exactly 1/16 of a given amount of protactinium-234 remains after 26.76 hours. What is the half life of protactinium – 234?

4. How many milligrams remain of a 15.0 mg sample of radium – 226 after 6396 years? The half=life of radium – 226 is 1599 years.

5. Technetium – 99 has been used as a radiographic agent in bone scans. If ^{99}Tc has a half-life of 6.0 hours, what fraction of the administered 100.0 g dose will remain after 2.0 days?

6. The half-life of polonium – 210 is 138.4 days. How many milligrams of an original 2.0 mg sample will remain after 415.2 days?

7. Assuming a half-life of 1599 years, how may years will be needed to decay 15/16 of a given amount of radium?

8. The half-life of cobalt – 60 is 10.47 minutes. How many grams of cobalt – 60 remain after 104.7 minutes if you start with 10.0 g?

9. A sample contains 4.0 mg of uranium – 238. After 4.46×10^9 years, the sample will contain 2.0 mg of uranium – 238. What is the half-life of uranium – 238?

10. A sample contains 16 g of polonium – 218. After 12 minutes, the sample will contain 1.0 g of polonium – 218. What is the half life of polonium – 218?

Unit 3 Review

Matching: Match the person in column B to the experiment, discovery or model in column A. Each person can be used more multiple times.

Column A	Column B
____1. Billiard Ball model	a. Chadwick
____2. Cathode Ray tube experiment	b. Democritus
____3. Atoms are mostly empty space	c. Rutherford
____4. Began Atomic Theory	d. Thomson
____5. Atoms are the smallest unit of matter	e. Dalton
____6. Plum Pudding model	
____7. Gold Foil Experiment	
____8. Neutrons make up the rest of the mass of the nucleus.	
____9. Atoms are divisible into smaller particles.	

Standard Nuclear Notation: Write the following in standard nuclear notation.

1. An element with 14 electrons and 16 neutrons
2. Curium- 249
3. Potassium with 22 neutrons
4. Rutherfordium- 257

Average Atomic Mass: Show ALL work!

1. Nitrogen has two isotopes. Nitrogen- 14 has a mass of 14.003074 amu and a percent abundance of 99.63 %. Nitrogen- 15 has a mass of 15.000108 amu and a percent abundance of 0.37. Calculate the average atomic mass of Nitrogen.

2. Calculate the average atomic mass of the unknown element. Identify this element.

Isotope	Atomic Mass (amu)	Percent Abundance (%)
X	23.9850423	78.99
Y	24.9858374	10.00
Z	25.9825937	11.01

3. Silicon- 28 has a mass of 29.98 amu and a percent abundance of 92.23 %. Silicon- 29 has a mass of 28.98 amu and a percent abundance of 4.67 %. Silicon- 30 has a mass of 29.97 amu. Calculate the average atomic mass of Silicon.

<u>Decay:</u>

Determine if the following isotopes are stable and explain your answer.

1. Mercury- 200

2. Tin- 124

3. Rhodium- 106

4. Bismouth- 209

5. Gallium- 66

Write the balanced equation for the following nuclear decay. Indicate if the starting isotope was above or below the band of stability for Beta decay, Electron capture and positron emission.

1. Alpha decay of Americum- 241

2. Beta decay of Hydrogen- 3

3. Electron capture of Aluminum- 26

4. Positron emission of Carbon- 11

5. Alpha decay of Platinum- 192

6. Beta decay of Phosphorus- 32

Half-life- Show ALL work!

1. After 4 half-lives, what mass of a 64.00 mg sample is remaining?

2. Arsenic- 72 has a half live of 26.0 hours. What percent of Arsenic- 72 will remain after 78.0 hours?

3. Iodine- 126 has a half-life of 13.0 days. A sample of Iodine-126 was originally 42.00 kg, and after Z hours only 5.25 kg remain. How much time in hours has passed?

4. If you have a 14.00 g sample of a radioisotope X, and after 4.5 hours only 1.75 g of radioisotope X remained, what is the half-life of radioisotope X?

Show ALL work!!!

1. Flourine-18 undergoes positron emission and has a half-life of 1.8 hours. Answer the following questions about this isotope.

   a. Write the balance equation for the nuclear decay of Fluorine- 18.

   b. Determine if the daughter product of Fluorine- 18 is stable.

   c. Calculate the mass of Flourine-18 that will remain in a 8.00 g sample after 4 half-lives.

   d. Calculate the time that passed in part c.

Identify the more stable isotope in each pair

33. a: $^{14}_{6}C$ ***or*** $^{12}_{6}C$

34. c: $^{200}_{80}Hg$ ***or*** $^{207}_{80}Hg$

35. b: $^{15}_{8}O$ ***or*** $^{16}_{8}O$

36. d: $^{34}_{16}S$ ***or*** $^{32}_{16}S$

37. Compare and contrast the models of the atom proposed by Thompson and Rutherford.

38. Why are electrons in a cathode-ray tube deflected by electric fields?