Topic III Quest Study Guide

A. Early Concepts: Democritus:

Democritus:

- Greek Philosopher
- 400 B.C.
- Matter is composed of atoms, which move through empty space
- Atoms are solid, homogeneous indestructible and indivisible
    - FALSE- subatomic particles (Protons, neutrons, electrons)
- Different kinds of atoms have different shapes and sizes
- size, shape, and movement of atoms determine the properties of matter
- Atoms are in constant motion
- atoms are able to join with other atoms to form different types of matter

No experimental evidence to back up his theory

Aristotle:

- Empty space cannot exist
- Matter is made of earth, air, fire, and water

Accepted for 200 years b/c people can't see "atoms"-more influential. ---> whole theory was FALSE *

B. Beginning of the Modern Model:

1. Mathematical nature of matter

- Combined ideas Dalton, Lavoisier, Proust
    - All matter is made up of tiny particles , which are molecules or atoms
    - Molecules can be broken down into atoms by chemical processes
    - Atoms cannot be broken down by physical or chemical processes
        - Lavoisier (Law of Conservation of Mass)
        - Proust (Law of Definite Proportions)
        - Formed 2 Laws of Chemistry:
    - **Law of Definite Composition:** The % by mass of an element in a compound is always the same
        - ex.)mass ratio of carbon to oxygen is carbon dioxide is always the same 1 C to 2 O.
    - **Law of Conservation of Mass:** In chemical reactions mass is conserved and is not created or destroyed
        - ex.) Dalton proposed the creation of new compounds through chemical reactions

2. Dalton's Atomic Model

- Dalton's Atomic Theory:

1. An element is composed tiny, indestructible, indivisible particles called atoms.
2. All atoms of the same element are identical and have the same properties
3. Atoms of different elements combine to form compounds
4. Compounds contain atoms in small whole number rations
5. Atoms can combine in more than one ratio to form different compounds, or simply chemical reactions involve the rearrangements of atoms. No new atoms are created or destroyed.

****Had experimental evidence to support his theory****

<u>Still accepted today:</u>

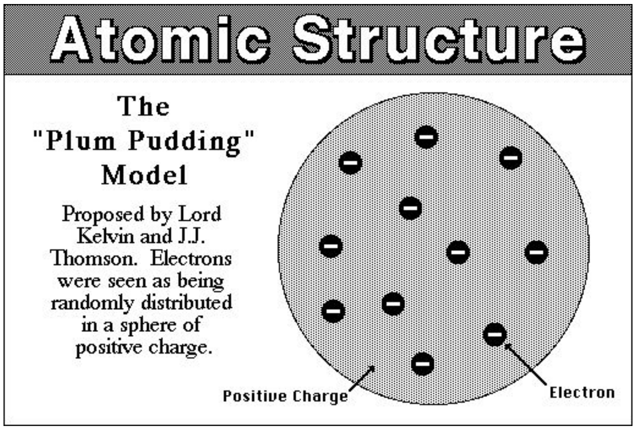
- Atoms of specific elements are different from those of another element
- Different atoms combine in simple whole number ratios to form compounds (Law of Conservation of Mass)
- In a chemical reaction, atoms are separated, combined, or rearranged. (Law of Definite Proportions)

<u>Dalton's Model Today:</u>

- 1st 2 suggestions-incorrect
    - Atoms are indestructible/indivisible:
        - Atoms are divisible
    - All atoms of the same element are identical:
        - subatomic particles were later discovered:
            - Proton with +1 charge
            - Electron with -1 charge
            - Neutron with neutral charge
            - Isotopes: different number of protons than neutrons
- Postulates 3,4,5 still accepted
- Billiard Ball Model: Solid sphere, indestructible, indivisible

<u>J. J. Thomson Plum Pudding Model</u>

- Evidence of subatomic particles (electrons [e-])



- Spherical cloud of positive charge
- Electrons (e-)

C. Composition of the Atom:

1. Matter's electrical connection

a. *anode/cathode rays*
b. *photoelectric effect*

1832: Michael Faraday

- Studied the effect of electricity on various solutions
- Coined the term "electrolysis" to define molecules splitting by electricity

1879: Sir William Crooke

- discovered the following properties of cathode rays
  - Fluoresce glass
  - travel in straight lines directly from cathode
  - deflected by magnets and electrical fields
  - make pinwheels spin; proving they have mass

1896: Henri Becquerel

- 1896 discovery of radioactivity
- Found that Uranium salts produce indivisible radiation when kept in dark
- idea that an element such as Uranium can produce radiation continuously is hard to accept--> breaks Law of Conservation of Mass
- Early in 20th century found 3 types of radioactive emission existed: gamma, beta, and alpha particles

The experiment:

- Several photographic plates and several crystals of Uranium
  - Plate 1: place one crystal directly on photographic plate
  - Plate 2: place sheet of glass in between crystal and plate
  - Plate 3: place thin aluminum sheet on top of plate
  - Then placed all 3 in dark for several hours

- **Results:**
    - Plate 1: Crystal in direct contact with plate--> showed strong blackening
    - Plate2: slightly weaker blackening
    - Plate 3: blackening which was much weaker, but nevertheless very clear
- **Conclude:** Uranium salts produce invisible radiation even when kept in dark
- Discovered radioactivity

Radioactive emission:

- Gamma (γ)rays
    - high energy "light"
- Beta (β) particles
    - high speed electron
- alpha (α) particles
    - 2+ charge-twice that of an electron and opposite in charge
    - Mass of particle is 7300 times an electron mass

1897: The structure of the Atom:

- Work done by JJ Thomson an English Physicist-proved atoms had pieces called electrons
- Cathode ray tube
- Electrodes were hooked to an anode (positively charged) and the cathode (negatively charged)
- A glowing beam flowed from the negative end to the positive end, called the cathode ray

Cathode Ray Tube (CRT):

- JJ Thomson discovered that atoms contain electrons using the cathode ray tube.
- **cathode ray tube:** sealed glass tube that contains gas and has separated metal plates connected to external wires. When a source of electrical energy is applied to the metal plates, a glowing beam is produced.
- Thomson became convinced that the glowing gas was caused by a stream of negatively charged particles coming from the metal plate
- **Concluded:** Since he got the same kind of negative particles, no matter what type of metal he used, he concluded that all types of atoms must contain these same negative particles (electrons).
- EXAMPLES (Today): "neon" signs, television picture tube or computer monitor

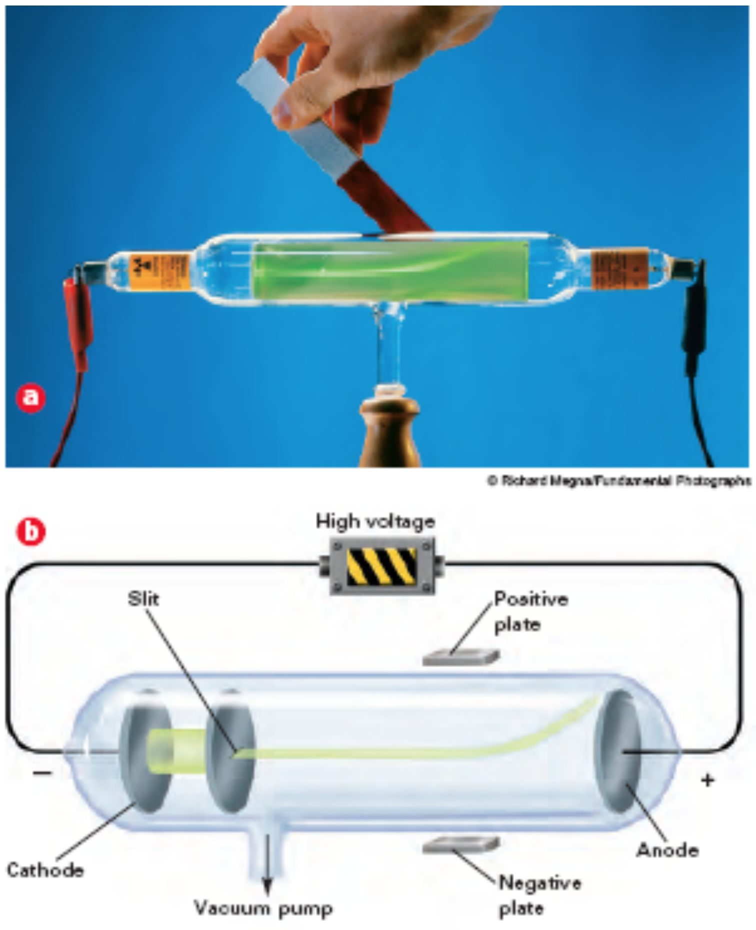


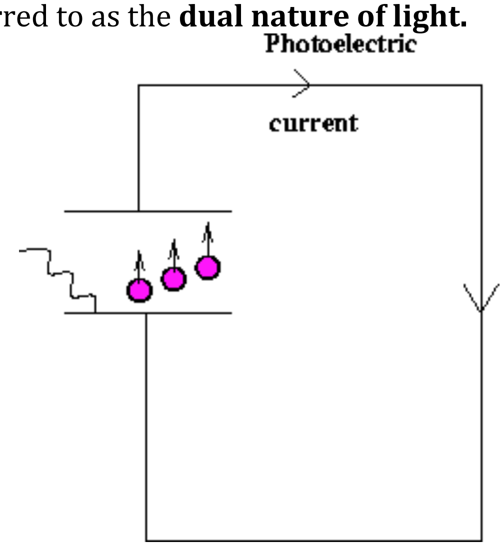
Figure 4.5 Thomson examined two ways that a cathode ray can be deflected: **a** by using a magnet, and **b** by using electrically charged plates. **Inferring** *If a cathode ray is attracted to a positively charged plate, what can you infer about the charge of the particles that make up the cathode ray?*

<u>Photoelectric effect:</u>

- An experiment that provides compelling proof of photon nature of light(particle nature of light) is the **photoelectric effect.**
    - light is shone at a metal plate, and it is found that electrons are ejected. These electrons then get accelerated to a nearby plate and a photoelectric current is established.
- Explanation first given by **Einstein** and it won him the Nobel Prize.
    - Each photon hits an electron in the metal, giving up energy to the electron. This can sometimes be enough energy to free the electron from the attractive forces holding it in the metal.
    - electron is then accelerated(or moves quickly) towards the other side, causing a flow of charges and hence a current.
    - This effect, which arises in devises such as burglar alarms, cannot be explained using a "wave" picture of light.
    - For example, it is found experimentally that the photoelectric current depends critically on the frequency of the light being used. If the frequency of the light is too low, then no current is observed. If the frequency of the light

used is too low, then no current is observed. Red light is the lowest frequency light and the violet is the highest frequency light in the visible spectrum.

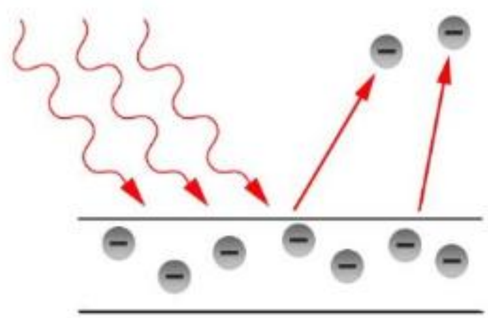
- <u>Conclusions from work of Einstein &Planck:</u>
    1. Energy is quantized. It can occur only in discrete units called quantum.
    2. Light has characteristics of both waves and particles. The phenomenon is sometimes referred to as the **dual nature of light.**



Photon: stream of tiny packets of energy

1905: <u>Albert Einstein:</u>

- Hypothesized that light was made up of particles
- "photon" or "particle" nature of light
- Light is shone on a metal plate and it is found that e- are ejected
- Each photon of light (bundle of light) hits an e-in the metal giving up its energy to the e-
- Can be enough energy to free e- from the attractive forces holding the metal
- Depends on the frequency of light used (candescent vs. UV)
- if frequency (energy) is too low, the e- is not emitted from metal.



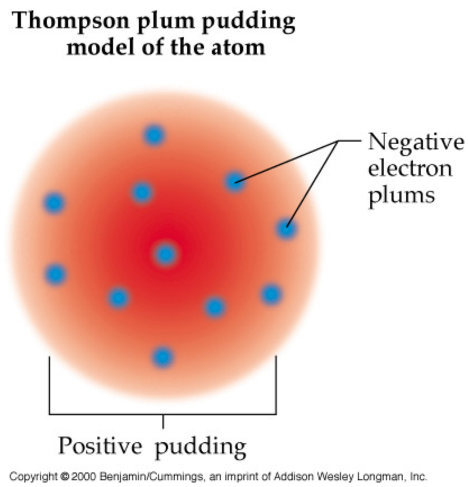
1906: <u>Hans Geiger:</u>

- Built a device that "clicks" when alpha particles (radioactive particles) hit it detecting radiation

2. Electrons: Thomson and Millikan
   a. discovering the electron & it's charge
   b. Thomson's atomic model

<u>Thomson's plum pudding model:</u>

- The atom is breakable
- Electrons are negative, so : need a positive charge to balance electrons because 2 negative charges repel each other
- Plum Pudding Model: Electrons are suspended in a positively charged electric field
- A lot of empty space in the atom to separate the electrons
- 1st evidence of subatomic particles
- e- are negative, so need a positive charge to balance electrons; in this model e- suspended in positively charged electrical field



1903: <u>Nagaoka</u>

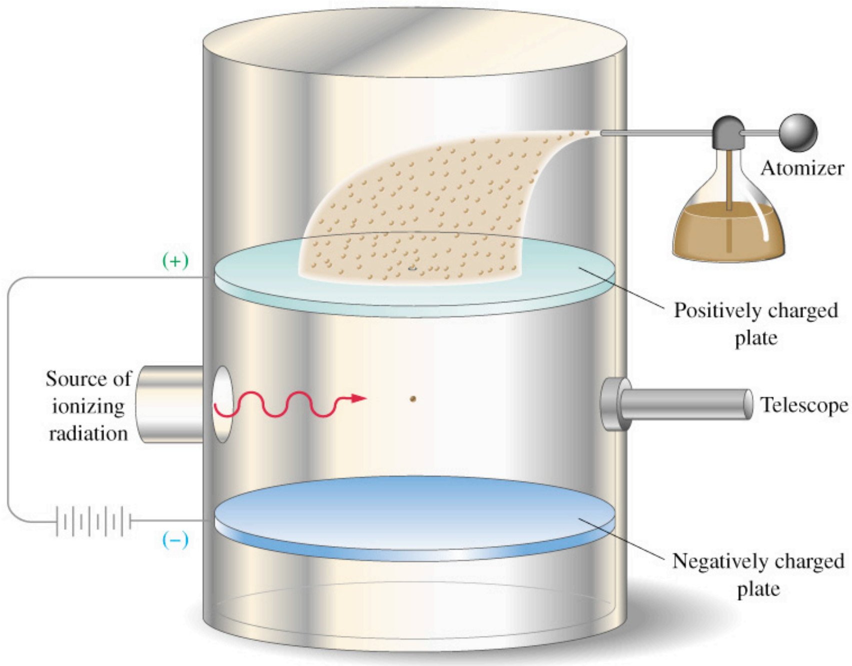
- Designed model of atom featuring flat rings of e- that revolved around a particle with positive charge
- Incorrect "planetary model"

<u>Millikan:</u>

- 1911; an American Scientist
- Oil drop experiment: Studied the motion of charged oil droplets in an electric field
- Determined the mass to charge ratio of an electron
- Electrons charge is -1; the mass is 9.11×10^{-28} g

<u>The Experiment:</u>

In 1909 Robert Millikan worked at the University of Chicago, performed very clever experiments involving oil drops. These experiments allowed him to determine the magnitude of the electron (1.60×10^{-19} Coulombs). With this value and the charge-to-mass ration determined by Thomson, Millikan was able to calculate the ass of the electron as 9.11×10^{-31} kg.



E. Goldstein:

- Discovered the proton is a positively charged subatomic particle that is 1840 times heavier than the electron

Chadwick:

- 1932, James Chadwick confirmed that the neutron has no charge, but the same mass as a proton
- Neutron charge is 0, the mass is 1.67 x 10^{-24} g

3. The Nucleus: Rutherford

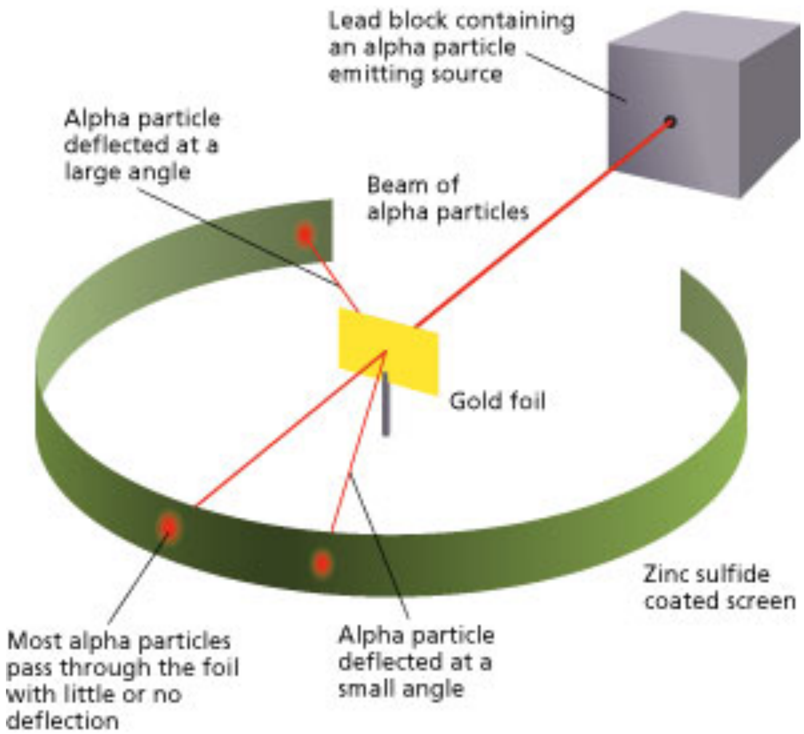
a. *Discovery of Radioactivity*

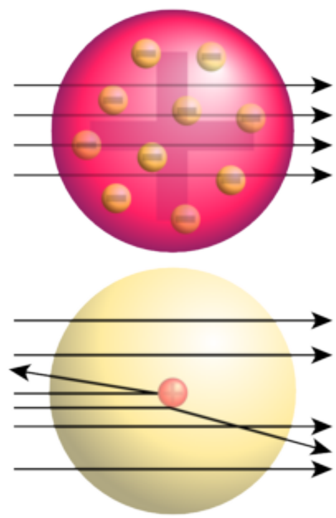
- See **Henri Becquerel**

b. *Rutherford's experiment*

Rutherford's Gold Foil Experiment:

- Ernest Rutherford-English physicist
- Believed in the Plum Pudding Model of the atom
- Designed an experiment to test the Plum Pudding Model
- Used radioactivity, and shot the positively charged alpha particles at a gold foil which was a few atoms thick
- If plum pudding model of the atom was correct, most alpha particles should pass through undeflected
- 98% of particles went straight through
- 2% of particles went through but were deflected by large angles
- About 0.01% bounced off the gold foil



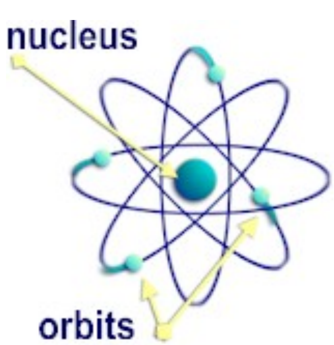


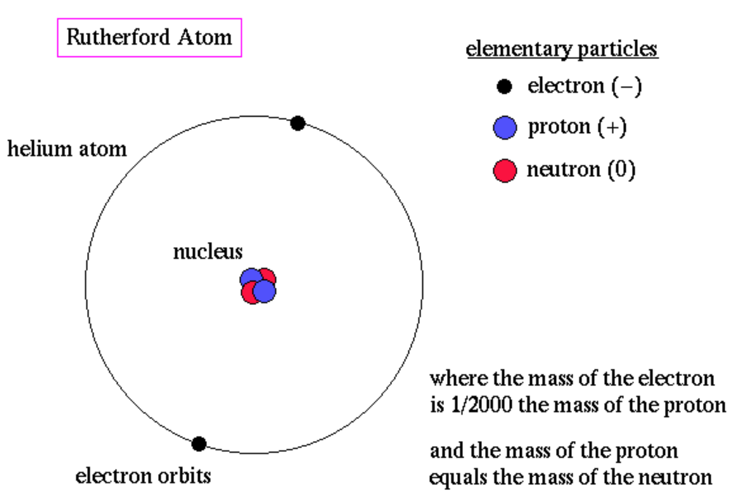
Rutherford & radioactivity:

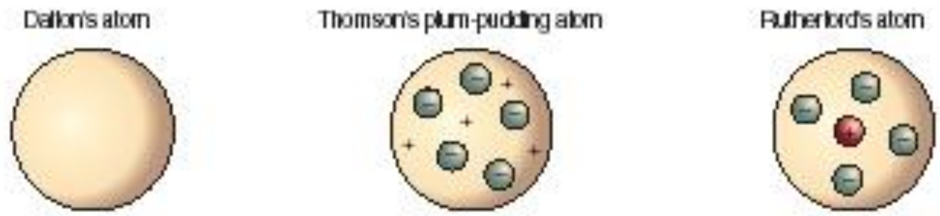
- 1908
- Three types of radiation
  - Alpha particles (α) composed of positively charged helium nuclei
  - Beta particles (β) composed of negative charged particles called electrons
  - Gamma rays (γ) composed of high energy radiation

Size: $\alpha > \beta > \gamma$

c. Rutherford's atomic model







D. Typical Properties:

- protons: positively charged
- neutrons: neutral (no) charge
- electrons-negatively charged

1. Atomic Sizes

Properties of Subatomic Particles:

Particle	Symbol	Relative Charge	Relative Mass compared to proton (Mass of p=1)	Actual Mass (g)	Location
Electron	e-	1^-	1/1840	9.11×10^{-28}	outside nucleus
Proton	P^+	1^+	1	1.67×10^{-24}	nucleus
Neutron	n^0	0	1	1.67×10^{-24}	nucleus

- Protons are much bigger than electrons
- The charge to mass ratio is much greater for electrons and much less fro protons (Electrons are packed with charge)

2. Atomic Number; Moseley

- Atomic #- The number of protons in the nucleus of an atom determines the **atomic number.**
- All atoms of the same element have the same number of protons and therefore the same atomic number; atoms of different elements have different atomic numbers. Thus, the atomic number identifies the element.
- An English scientist, **Henry Moseley** determined the atomic numbers of the elements through the use of x-rays.

3. Atomic Masses

- Since the actual masses of subatomic particles and atoms themselves are very small numbers when expressed in grams, scientists use atomic mass units (amu) instead. An atomic mass unit is defined as ½ the mass of a carbon atom. Thus, the mass of any atom is expressed relative to the mass of one atom of carbon-12, which is sometimes called the unified atomic mass unit (u) or the dalton.

- The sum of the # of protons and the # of neutrons in the nucleus is called the mass number.
    a. relative mass scale: (see above)
    b. isotopes: same number of protons, but different number of neutrons
    - **See Max's Study Guide**
    c. average isotopic mass; calculations (4.1 b)
- The Average atomic mass can be calculated by multiplying the atomic mass of each isotope by its relative abundance (expressed in decimal form) and adding the results.
- Size of one carbon atom = 12 amu

Counting Atoms:
Dimensional Analysis

ex) Calculate the mass, in amu, of a sample of Al that contains 75 atoms of Al.

$$75 \text{ atoms Al} \times \frac{27.0 \text{ amu}}{1 \text{ Al Atom}} = 2024 \text{ amu} = 2.0 \times 10^3 \text{ amu Al}$$

? Oxygen atoms = 288 amu?

$$288 \text{ amu} \times \frac{1 \text{ Oxygen atom}}{16.0 \text{ amu}} = 18 \text{ atoms of O (18.0)}$$

Law of Definite Proportions
How much of an element is in each compound

H_2O(H) 2(1.0 g)= 2.0 g
(O) 16.0 g + 16.0 g
18.0 g

$$\text{\% Mass (\% Composition)} = \frac{\text{mass element}}{\text{mass compound}} \times 100$$

$$\%H = \frac{2.0 \text{ g}}{18.0 \text{ g}} \times 100 = 11.1\ \%$$

$$\%\ O = \frac{16.0 \text{ g}}{18.0 \text{ g}} \times 100 = 88.9\ \%$$

$Ca_3(PO_4)_2$ (Ca) 3(40.1 g)=120.3 g
(P) 2(31.0 g)= 62.0 g
(O) 8 (16.0g)= 128.0 g
310.3 g

$$\%\ Ca = \frac{120.3 \text{ g}}{310.3 \text{ g}} \times 100 = 38.8\ \%$$

%P = $\frac{62.0 \text{ g}}{310.3 \text{ g}}$ x 100 = 20.0 %

% O= $\frac{128.0 \text{ g}}{310.3 \text{ g}}$ x 100 =41.3 %

Short Hand Notation:

Nuclear Notation:

Mass---->
Atomic #------>

$${}^{235}_{92}\text{U}$$

Hyphen Notation:
U-235 (mass)

Mass

e- = 9.11 x 10^{-22}
P=1.67 x 10^{-24}
n=1.67 x 10^{-24}

C-12 (GIVEN)
6 P   6(1.67 x 10^{-24})
6 n   6(1.67 x 10^{-24})
6 e   negligible

Relative Scale:
Atomic Mass
- Unit (amu)
- 1 amu= 1/2 mass

C-12
6 P (in C-12)= 6 amu
6 n (in C-12)$^+$ = 6 amu
12 amu

Average Atomic Mass weighed:
Average of the masses of all naturally occurring is isotopes for that element.

Depends on:

- Mass of isotope
- % abundance (how much ?)
- Average Atomic Mass = (mass isotope) x (% abundance in decimal form)

Cl-35=34.969 amu 75.78 %
Cl-37= 36.966 amu 24.22 %

Average atomic= (34.669 amu) (0.7578) + (36.966 amu) (0.2422)
= 24.496 amu + 8.957 amu
= 35.433 amu
(35.457 amu on periodic table)

Isotope	Mass	% abundance
X	6.015	7.59 %
Y	7.016	92.4 %

(6.015) (0.0759) + (7.016)(0.9241)
0.457 + 6.483
6.940 amu Lithium