INSIDE THE ATOM

I. Models of the atom – the basic unit of matter
   A. More than 2500 years ago, in 530 BC, Democritus, a Greek philosopher, proposed that matter was composed of tiny particles called *atoms*; atoms, in Greek, means that which cannot be divided.
   B. During the 18th century, scientists found that some substances, that they named **elements,** cannot be broken down into simpler substances; they theorized that:
      1. matter is made up of elements.
      2. elements are made up of one kind of atom.
   C. John Dalton, early nineteenth century English schoolteacher,
      1. pictured an atom as a hard sphere. or marble
      2. proposed in 1808, that:
         a. matter is made up of atoms
         b. atoms cannot be divided into smaller pieces
         c. all the atoms of an element are exactly alike
         d. different elements are made of different kinds of atoms
   D. William Crookes, English scientist.
      1. discovered in 1870, using a cathode-ray tube (CRT), that streams of particles, or rays, flowed from a **cathode** – an electrode with a negative charge, to an **anode** – an electrode with a positive charge.
   E. J. J. Thomson, English physicist.
      1. repeated the CRT experiments.
         a. in 1897, concluded that cathode rays were charged particles
         b. later discovered that cathode rays:
            1). were produced regardless of the element used as the cathode
            2). were attracted to the positively charged anode and therefore were negatively charged particles; which are now called **electrons** – negatively-charged particles that exist in an electron cloud formation around an atom's nucleus.
      2. pictured an atom as a positively charged sphere with negatively charged electrons spread evenly throughout thus resulting in a neutral atom; this model is sometimes called the "Plum Pudding Model." also sometimes referred to as the "Chocolate Chip Cookie Model."

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400 nm = .000 000 400 m

F. Ernest Rutherford, English scientist.
   1. in 1906 devised the "gold foil experiment"
      a. fired fast moving **alpha particles** at a 400 nm thick sheet of gold foil surrounded by a screen that detected a charged particle by giving off a flash of light when hit.
         1). **alpha particles** are:
            a). positively charged bits of matter,
            b). come from unstable atoms
            c). consist of two protons and two neutrons,
            d). are repelled by positively charged particles of matter
      b. expected alpha particles to pass straight through the gold foil with only a few minor changes in their path.
      c. some alpha particles ricocheted and hit the screen at large angles back toward the source indicating a large positive charge.
   2. proposed a new model of the atom; hypothesized that:
      a. the center of an atom was the **nucleus,** an incredibly small region, which contained:
         1). almost all the mass of an atom.
         2). all the positively charged particles of an atom.
      b. the rest of an atom is empty space occupied by almost-massless electrons. (mass: 0.000 548 580 atomic mass units)
   3. in 1919, the name **proton** was given to the positively charged particles of atoms; proton, in Greek, means "first" because protons were the first identified building blocks of the nucleus.

G. Other developments and models.
   1. scientists proposed that another particle, later called the **neutron**, was located inside the nucleus.
      a. the neutron:
         1). had about the same mass as a proton.
         2). was electrically neutral
      b. scientists developed a new model of the atom consisting of:
         1). a tiny nucleus packed with:
            a). positively charged protons (mass: 1.007277 amu)
            b). neutral neutrons (mass: 1.008665 amu)

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2). negatively charged electrons occupying the space surrounding the nucleus.
3). no. of protons = no. of electrons

2. Niels Bohr, twentieth century Danish physicist, developed the model of the atom known as the "Bohr Model" which showed the energy levels in which electrons orbit the nucleus.
3. scientists soon after determined that it was impossible to know the exact location of an electron at any particular moment.
4. physicists proposal that electrons were not particles, but waves, led to the "Wave Model " or as it is better known the "**Electron Cloud** Model" in which the electrons are more likely close to the nucleus but could be anywhere as the cloud has no firm boundary.

H. Size and scale of an atom: if the nucleus is the size of a table-tennis ball, the diameter of the atom is more than 2.4 km.

II. The Nucleus

A. Identifying Numbers

1. atoms of different elements contain different numbers of protons.
   a. the number of protons in the nucleus of an atom:
      1). is that elements **atomic number**.
      2). never changes without changing the identity of the element.
2. atoms of the same element that have different numbers of neutrons are called **isotopes.**
   a. neutrons in carbon:
      1). most carbon atoms have 6 neutrons
      2). some carbon atoms have 7 neutrons
      3). some carbon atoms have 8 neutrons
   b. isotopes of carbon:
      1). carbon-12, carbon-13, carbon-14

Atomic mass

3. **average atomic mass -** the mass of the mixture of the isotopes for an element. (dec. no. on periodic table)
4. **mass number** – the number of neutrons and protons in the nucleus of an atom. (rounded number)
   a. the mass number minus the atomic number gives you the number of neutrons.

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★ 5. the force that holds the protons and neutrons together in the nucleus of the atom is called the strong nuclear force.

B. **Radioactive Decay** – release of nuclear particles and energy from unstable atomic nuclei.
   1. occurs especially in heavier elements, like uranium and plutonium, where there are too many or too few neutrons
   2. **transmutation** occurs when one element changes into another through radioactive decay,
      a. transmutation by ejecting nuclear radiation in the form of energy and alpha particles (two protons and two neutrons).
         1). in smoke detectors <u>americium-241</u> loses 2 protons and 2 neutrons and transmutates into neptunium
      b. transmutation by ejecting a **beta particle** (a high-energy electron that comes from the nucleus.)
         1). beta particles result from an unstable neutron splitting into an electron and a proton.
         2) in hydrogen-3 one neutron is converted to a proton and a beta particle and transmutates into a helium isotope.

C. Rate of decay of a nucleus is measured by its **half-life** – time needed for one half of the mass of a sample of a radioactive isotope to decay.
   ★ 1. the activity (energy) level of the isotopes determines the length of the half-life. High energy isotopes decay more quickly, and thus have shorter half-lives, but release more activity and are therefore more radioactive.
   2. decay goes on at a steady pace unaffected by conditions such as weather, pressure, magnetic or electrical fields or chemical reactions.
   3. half-lives range in length from fractions of a second to billions of years.
   4. <u>carbon-14</u> dating - method archaeologists use to determine the age of artifacts and fossils using radioactive decay.

D. Making Synthetic Elements - elements that are man-made.
   1. particle accelerators smash alpha and beta particles into a large nucleus of an atom transmutating it into an atom of another element

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with a higher atomic number.

2. elements 93 - 116 and element 118 are synthetic elements.

E. Uses of radioisotopes or "tracer elements":
   1. medical uses
      a. iodine-131: used in diagnosis of thyroid gland disorders.
      b. tenechtium-99: used in the diagnosis of tumors and fractures and for tracing a variety of bodily processes.
   2. environmental uses:
      a. phosphorus-32: used to determine how plants use phosphorus for growth and reproduction.
      b. radioisotopes can be placed in pesticides and used to determine how far they travel and how long they last in the ecosystem.
      c. radioisotopes can be used to determine how well plants absorb fertilizers.
      d. radioisotopes can be used to trace water resources in arid regions.