Nuclear Terms and Notation

- **Protons:** positively charged particles found in the nucleus of the atom
  - The number of protons determines the element type
  - In a neutral atom, the number of protons is equal to the number of electrons
  - The **atomic number (Z)** is the number of protons in the nucleus of an atom

- **Neutrons:** neutral particles found in the nucleus of the atom
  - The **neutron Number (N)** is the number of neutrons found in the nucleus of an atom

- **Atomic Mass/Mass Number (A):** the total number of protons and neutrons in an atom because the neutrons and protons are the most massive component of an atom
  - **Nucleons** is another term for protons and neutrons in an atom's nucleus
  - The atomic mass number is usually indicated as a number attached to the back of an element name (ie. carbon – 14)

- **Isotopes:** atomic nuclei that have the same number of protons but different number of neutrons
  - Example: carbon-12, carbon-13, and carbon-14 (↙ atomic mass # (A); ↑ indicates atomic # (Z))

- The nucleus of an atom is represented with the following nuclear notation

$^{A}_{Z}X$ — atomic mass # → A; atomic # → Z; ← element symbol

where $A = N + Z$

$\therefore N = A - Z$

proton = $^{1}_{1}P$

neutron = $^{1}_{0}n$

EXAMPLES

1. How many neutrons are contained in a gold nucleus $^{197}_{79}Au$?

$A = 197$ $\quad A = Z + N$

$Z = 79$ $\quad \therefore N = A - Z = 197 - 79 = 118$

$\boxed{N = 118}$

2. How do the nuclei $^{12}_{6}C$, $^{13}_{6}C$, and $^{14}_{6}C$ differ? How are they the same?

- all elements are carbon and contain 6 protons (ie. have same atomic #)
- all contain different number of neutrons ∴ will all have different masses

on pg. 313 #1 Con.t :)

Isotopic Notation	Name	Atomic Number (Z)	Atomic Mass (A)	Number of neutrons (N)
$^{2}_{1}H$	hydrogen-2 (deuterium)	1	2	1
$^{210}_{86}Rn$	radon-210	86	210	124
$^{45}_{20}Ca$	calcium-45	20	45	25
$^{38}_{19}K$	Potassium-38	19	38	19
$^{14}_{7}N$	nitrogen-14	7	14	7
$^{230}_{89}Ac$	actinium-230	89	230	141
$^{26}_{12}Mg$	magnesium-26	12	26	14
$^{144}_{63}Eu$	europium-144	63	144	81

Nuclear Reactions

- A **nuclear reaction** is a reaction in which one element is converted into another element
  - A *nuclear reaction* is also called a **transmutation** or **nuclear/radioactive decay**
  - The **parent element** is the original/initial element in the nuclear reaction and the **daughter element** the element produced in the nuclear reaction
- A nuclear reaction is different from a chemical reaction because a chemical reaction just involves atoms rearranging, not atoms of one element converting into a new element
  - EXAMPLES:

    Chemical Reaction: $2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O$ same type & # of elements before and after

    Nuclear Reaction: ${}^{13}_{6}C + {}^{4}_{2}He \rightarrow {}^{16}_{8}O + {}^{1}_{0}n$ carbon & helium converted into oxygen
- ✱ There are many types of nuclear reactions, but all nuclear reactions are governed by the conservation of charge (principle #7) and the conservation of mass/nucleons (principle #8)

- EXAMPLE: A uranium-235 nucleus absorbs a neutron and then splits into a bromine-87, three neutrons, and one other daughter element. What is the unknown daughter element produced by this reaction?

$${}^{235}_{92}U + {}^{1}_{0}n \rightarrow {}^{87}_{35}Br + 3\,{}^{1}_{0}n + {}^{x}_{y}?$$

nucleons: $235 + 1 = 87 + 3(1) + x$

$236 = 90 + x$

$146 = x$

charge: $92 + 0 = 35 + 3(0) + y$

$92 = 35 + y$

$57 = y$

$\therefore {}^{x}_{y}? = {}^{146}_{57}La$

- Most nuclear reactions give off one of more of the following types of radiation
  1. Alpha radiation
  2. Beta radiation
  3. Gamma radiation

ALPHA RADIATION

- An alpha particle is a helium atom $({}^{4}_{2}He$ or ${}^{4}_{2}\alpha)$

- To produce/release an alpha particle, the *parent nucleus/element* must lose/release two protons and two neutrons

$${}^{A}_{Z}X \longrightarrow {}^{A-4}_{Z-2}Y + {}^{4}_{2}\alpha$$

parent → daughter + alpha particle

- EXAMPLE: Write out the alpha decay of uranium-238.

$${}^{238}_{92}U \longrightarrow {}^{234}_{90}Th + {}^{4}_{2}\alpha$$

nucleons: $238 \rightarrow 234 + 4$ ✓

charge: $92 \rightarrow 90 + 2$ ✓

BETA RADIATION

1. Beta-Negative (β^-) decay
   - A neutron in the nucleus is transformed into a proton, and in the process emits an *electron* and an extremely small neutral particle known as **antineutrino** ($\bar{\nu}$)
     - An electron is a beta-negative (β^-) particle and has no significant mass when compared to a neutron or proton ($^{0}_{-1}\beta$)

$$^{1}_{0}n \longrightarrow ^{1}_{1}p + ^{0}_{-1}\beta + \bar{\nu}$$

neutron → proton + electron + antineutrino

   - EXAMPLE: Write out the β^- decay for lead-212.

$$^{212}_{82}Pb \longrightarrow ^{212}_{83}Bi + ^{0}_{-1}\beta + \bar{\nu}$$

nucleons: 212 = 212 + 0 ✓

charge: 82 = 83 + (-1) ✓

2. Beta-Positive (β^+) decay
   - A proton in the nucleus is transformed into a neutron, and in the process emits a *positron* and a *neutrino*
   - A **positron** (e^+) is the antimatter/antiparticle to an electron and has the same mass and charge magnitude as an electron, but just the opposite charge
     - An positron is a beta-positive (β^+) particle and has no significant mass when compared to a neutron or proton ($^{0}_{+1}\beta$)
   - A **neutrino (ν)** is an extremely small neutral particle and is the antimatter/antiparticle to the antineutrino.

$$^{1}_{1}p \longrightarrow ^{1}_{0}n + ^{0}_{+1}\beta + \nu$$

proton → neutron + positron + neutrino

   - EXAMPLE: What isotope will β^+ decay of thallium-202 produce? Write out this process.

$$^{202}_{81}Tl \longrightarrow ^{202}_{80}Hg + ^{0}_{+1}\beta + \nu$$

∴ mercury-202 produced.

nucleons: 202 → 202 + 0 ✓

charge: 81 = 80 + (+1) ✓

GAMMA (γ) RADIATION

- Most nuclear reactions are accompanied by the release of energy in the form of a *gamma ray*.
- Recall that a gamma ray is just a high energy photon (a bundle of energy) from the EMR spectrum
- ✳ Gamma radiation is not a nuclear reaction/transmutation by itself as one element is not converted into another, energy is simply being released

$$^{12}_{6}C \longrightarrow ^{12}_{6}C + \gamma$$

gamma

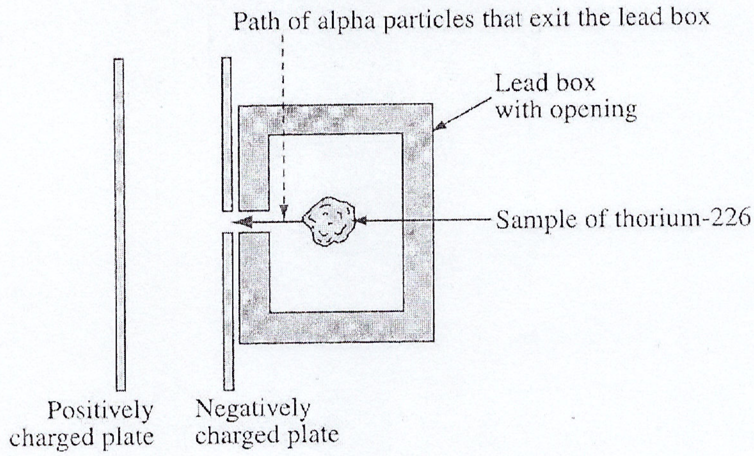
*****Now try pg. 315 #1a,d,e, 2-4, 6, 7, 11c & Practice Problem (challenger)*****

Practice Problem

Use the following information to answer the next question.

A sample of thorium-226 is stored in a lead box, as shown below. Thorium-226 undergoes alpha decay. The lead box has a small opening on the left side to allow a stream of alpha particles to escape.

Top-Down View of Apparatus



In the sample, a nucleus of thorium-226 is at rest when it undergoes alpha decay. The daughter nucleus produced, radium-222, has a mass of 3.67×10^{-25} kg and moves to the right at 3.10×10^{5} m/s immediately after the decay. The thorium-226 nucleus, the radium-222 nucleus, and the alpha particle form an isolated system.

To the left of the lead box are two parallel plates, one positively charged and the other negatively charged, that together produce a uniform electric field. The parallel plates are 2.00 cm apart. The escaping alpha particles are stopped by the electric force just before they reach the positively charged plate. The complete apparatus is in a vacuum.

1. Determine the magnitude of the electrical force acting on an alpha particle. **[4.87×10^{-11} N]**

$\vec{E} = \frac{\vec{F}}{q}$

$\vec{E} = \frac{\Delta V}{d}$ → $\Delta V = \frac{\Delta E}{q} = \frac{E_{kf} - E_{ki}}{q}$ ($E_{kf} = 0$)

$E_k = \frac{1}{2}mv^2$

↓

conservation of momentum