Chapter 25 – Nuclear Chemistry

I. Natural radioactivity

A. Nuclear reaction is any reaction where the **nucleus** of an atom changes composition.

B. **Radioactivity** – spontaneous emissions accompanying changes in nuclei of atoms.

C. **Protons** are positively charged and hence, repel each other. So, the presence of neutrons is required to keep the nucleus form flying apart. As the number of protons in the atom increases, a larger number of **neutrons** are required to maintain stability of the isotope. For most elements, there is a range over which the number of neutrons is just right to hold together a nucleus. If you have too many or too few neutrons can cause an isotope to be radioactive. All elements above **20** have more neutrons than protons.

D. 3 major types of radiation:
   1. **Alpha** particle radiation
   2. **Beta** particle radiation
   3. **Gamma** rays

E. Penetrating power of the radiation:
   1. Alpha = **low penetrating** (0.05mm body tissue) shielding would be **clothing**.
   2. Beta = **moderate penetrating** (can be stopped by a sheet of Al that is 4 mm thick) shielding would be **metal foil.**
   3. Gamma = **most penetrating** – needs 6" lead or 3' of concrete.

F. Human health problems:
   1. Alpha = are **deadly**, however, you need to **eat** something contaminated with an alpha emitter or inhale it.
   2. Gamma = like **x-rays** – can damage your genetic code if you have a large exposure. Small exposures are fine – but, that is why the physician places a lead vest around you while taking x-rays.

G. Ability to ionize gases.
   1. Alpha = **greatest**.
   2. Beta = **middle**
   3. Gamma = **least.**
   - ❖ Smoke detectors take advantage of the ionization effect of alpha particles. They contain a small piece of radioactive **Americium-241**, which ionizes the air in the detector and carries a small electrical current. The smoke disrupts the ionization effect of the alpha particles and the current and therefore triggers the alarm.

II. Equations for natural radioactivity.

A. **Transmutation** – the change of a radioactive element into another element.

B. **Radioactive decay** – changes that occur in the composition in radioactive materials as they give off alpha and beta particles and gamma rays.

C. Alpha particle - α

1. Is essentially a **Helium** nucleus = $^{4}_{2}He$ = 2 neutrons and 2 protons.
2. An atom emitting an alpha particle decreases its atomic number by **2** and the mass number by **4** and a new element is formed.

D. Beta particle - β
1. It is what you get when a neutron decays into a **proton** and a charged particle.
2. The atom that undergoes beta decay increases its atomic number by 1, the mass number remains the same and a new element is formed.
3. So, a **beta** particles could be written as:
$^{1}_{0}n \rightarrow {}^{1}_{1}H + {}^{0}_{-1}e$

E. Gamma rays – γ
1. They have **no** charge.
2. They have **no effect** on the mass number or the atomic number.
3. They are just high-energy light rays similar to **x-rays**.

F. **Decay series** – the series of changes that radioactive substances travel as they give off alpha and beta particles until they finally become stable, non-radioactive substances.

G. **Fission** the splitting of nucleus a nucleus into smaller particles. This is the type of reaction in **nuclear bombs**.
1. A traditional nuclear bomb comes in two forms, a **Uranium** bomb or a **Plutonium** bomb.
2. A Uranium bomb works by having a **critical mass** of Uranium-235 coming together. This bomb actually has two large pieces of Uranium where one is fired into the other to reach the critical mass. When this happens the reaction takes place and you see the large mushroom cloud produced.
3. For a Plutonium bomb the **Plutonium-239** must actually be compressed to reach a critical mass. This means there must be a series of perfectly timed explosions to cause the Plutonium to **implode** and then go nuclear.

H. **Fusion** when smaller particles come together to form larger particles. This takes place in the **sun**.

III. Artificial radioactivity

A. **Cyclotron** – a devise used to accelerate charged particles. These charged particles are slammed into a target to form new elements.

B. **Artificial radioactivity** – spontaneous radioactive emissions from a substance not found in nature, i.e. new element created in cyclotron. This form of radioactivity comes from laboratory bombardment of natural or synthetic substances with particles. The resulting new element can be radioactive and have radioactive isotopes. Therefore, having artificial radioactivity when the isotopes decay.

C. **Synthetic elements** – human made elements that do not exist in nature. Several of these elements fill gaps that formally existed in the periodic

table and they have extended the periodic table. Filling a gap = element 43 (Technetium), 87 (Francisum), etc. All the elements above **92** are radioactive.

IV. Half-Life and measurement of radioactivity

A. **Half-life** – the amount of time required for one half of any given mass of a radioactive isotope to decay.

B. **Example:** Strontium-90 (2.500 g was formed in 1960 atomic explosion at Johnson Island at the Pacific test site. The half-life is 28 years. In what year will only 0.312 g of Strontium-90 remain?

Half life:	**Amount**	**Year**
0	2.500 g	1960
1	1.25 g	**1988**
2	0.625 g	**2016**
3	0.312 g	**2044**