WELCOME TO PERIOD 16: IONIZING RADIATION

Homework #15 is due today.
How do nuclei become stable?
What is ionizing radiation?
What are neutrinos?
Mass is converted into energy

The mass of unbound protons and neutrons is greater than their total mass when these protons and neutrons are bound into a nucleus.

This difference in mass provides the binding energy – the energy released when nuclei form.

This is the mass $M$ in $E = Mc^2$
Nuclear/chemical/physical changes

**Nuclear reactions** involve changes to the nuclei of atoms that result in the formation of atoms of new elements.

**Chemical changes** involve making and breaking chemical bonds to create new molecules.

**Physical changes** involve no changes to the identity of atoms or molecules.
Nucleus stability

Stable nuclei have....

- 83 or fewer protons.
- the same number of protons and neutrons for light elements with 20 or fewer protons.
- more neutrons than protons for elements with more than 20 protons.
Fundamental forces produce stable nuclei

- The **weak nuclear force** adjusts the relative numbers of neutrons and protons to produce stable nuclei.
- The **strong nuclear force** holds protons and neutrons together in atomic nuclei.
- The strong force overcomes the repulsive **electromagnetic force** among positive protons.
Radioactive nuclei

- Materials containing atoms with unstable nuclei are radioactive.
- As unstable nuclei decay, they give off ionizing radiation.
- **Ionizing radiation** is radiation that strips electrons from atoms, turning the atoms into charged ions.
Ionizing radiation

Unstable nuclei can give off these types of ionizing radiation:

- **Alpha particles** $\alpha$ are helium nuclei $^{4}_2\text{He}$ (2 neutrons and 2 protons)
- **Beta particles** are $\beta^-$ electrons $^0_{-1}\text{e}$ or $\beta^+$ antielectrons $^0_{+1}\text{e}$
- **Gamma particles** $\gamma$ are very high energy photons.
Gamma particles

Gamma particles are high energy, short wavelength radiant energy.
Radioactive decay of unstable nuclei

Unstable nuclei become more stable by emitting alpha, beta, or gamma particles.

- **Large unstable nuclei have 83 or more protons.**
  
  Large nuclei can become more stable by reducing the nucleus size.

- **Small unstable nuclei with 20 or fewer protons have unequal numbers of neutrons and protons.**

Small nuclei become more stable by changing neutrons into protons or protons into neutrons.
Cloud chamber

- Alcohol vapor in the cloud chamber is supercooled by dry ice (frozen carbon dioxide).

- Radioactive sources emit ionizing radiation.

- These ions seed the supercooled alcohol vapor and form tiny droplets around the ions, leaving visible tracks.

- The tracks can also reveal the ionization density of the source, since some tracks appear thicker than others.
Cloud chamber ionization trails

Source: wikimedia.org/wikipedia/commons/1/1b/Cloud_chamber_bionerd.jpg
Conservation of charge and nucleons

Conservation of charge: The number of positive and negative charges (Z) on each side of the reaction must be equal.

Conservation of nucleon number: The number of nucleons (protons and neutrons, A) on each side of the reaction must be equal.

\[ ^{232}_{90}\text{Th} \rightarrow ^{228}_{88}\text{Ra} + ^{A}_{Z}\text{X} \]

\[ ^{238}_{92}\text{U} \rightarrow ^{4}_{2}\text{He} + ^{A}_{Z}\text{X} \]
Conservation of energy: neutrinos

Conservation of Energy means that the energy of reaction products must equal the energy of the reactants.

• Particles called neutrinos (ν) or antineutrinos (ν̅) are emitted in beta decays so that the energy of the reaction products equals the energy of the reactants.

• Neutrinos have no charge and very little, if any, mass.
\[ ^1_1 p \rightarrow ^1_0 n \]

Conservation of charge requires a positive antielectron.

\[ ^1_1 p \rightarrow ^1_0 n + ^0_{+1} e^+ \]

When an antielectron is emitted, a neutrino is also emitted.

\[ ^1_1 p \rightarrow ^1_0 n + ^0_{+1} e^+ + ^0_0 \nu \]

What does the spring represent? Energy!

\[ ^1_1 p \rightarrow ^1_0 n + ^0_{+1} e^+ + ^0_0 \nu + \text{energy} \]
Conservation of leptons

Electrons and neutrinos are examples of leptons. To conserve leptons, whenever a lepton is emitted, an antilepton must also be emitted.

- An antineutrino $\bar{\nu}$ is emitted with an electron $-1\, e$
- A neutrino $\nu$ is emitted with an antielectron. $0\, e$
**β- decay**

An unstable nuclei with too many neutrons changes one neutron into a proton. \( ^1_0 n \rightarrow ^1_1 p \)

Conservation of charge requires a negative electron. \( ^0_{-1} e \)

\[ ^1_0 n \rightarrow ^1_1 p + ^0_{-1} e^- \]

When an electron is emitted, an antineutrino is emitted \( \bar{\nu} \)

\[ ^1_0 n \rightarrow ^1_1 p + ^0_{-1} e^- + ^0_0 \bar{\nu} \]

Energy is also emitted.

\[ ^1_0 n \rightarrow ^1_1 p + ^0_{-1} e^- + ^0_0 \bar{\nu} + \text{energy} \]
Gamma particles

Gamma particles are high energy, short wavelength radiant energy. They have no mass or charge.

A nucleus can be in an excited state. When the nucleus decays to a lower energy state, it emits a gamma particle. During gamma decay, energy is given off. The number of neutrons and protons remains constant.
Oxygen-14

- Why is oxygen-14 unstable? $^{14}_8\text{O}$
- What change to the nucleus would make it stable?
- Is this $\beta^+$ or $\beta^–$ decay?
- Is the nucleus still an isotope of oxygen?
BEFORE THE NEXT CLASS…

✓ Read textbook chapter 17.
✓ Complete Homework Exercise 16.
✓ Print out Activity Sheet 17.