**Decay #1: Alpha Decay**

**Alpha Decay**: Since an alpha particle represents a helium nucleus, we will be losing two protons and two neutrons from our parent nuclide. A general reaction is seen below, followed by an actual example of alpha decay. Again, we must make sure that we account for all species!





Notice that when you add the atomic masses of the daughter 222-Rn with 4-He you get the same atomic mass that appears in the parent 226-Ra (222+4 = 226). And when you add the atomic numbers of the daughter 222-Rn with 4-He you get the same atomic number that appears in the parent 226-Ra (86+2 = 88). Since alpha decay involved the loss of a helium nucleus, you are losing protons. The product in an alpha decay will be a different element – it will be the element that is 2 atomic numbers away! Also, the mass difference will be 4 amu different between the parent and the daughter species.

Smoke detectors work by alpha decay. Americium-241 is inside smoke detectors, and when smoke particles enter the detector the alpha particles released by the americium atoms in alpha decay are caught by the smoke particles, which activates the smoke detector's alarm system. Gaseous radon in the soil is an alpha particle emitter. Breathing in radon gas can damage lung cells due to the alpha particles that the gas molecules emit.

Alpha Particle X-Ray Spectroscopy (APXS) is a method of determining the elemental composition of substances such as rocks and soil. The alpha particles come from an alpha decay reaction, usually of curium-244. NASA used APXS in its rover missions to Mars, including the Pathfinder missions, to determine what elements are present in Martian rocks.

A new cancer treatment, targeted alpha therapy (TAT), uses alpha decay to kill cancer cells. Lead-212 is attached to a carrier molecule, which when ingested travels to the site of the tumor and gives off alpha radiation, killing all cells in the area.



**Decay #2: Beta Decay**

**Beta Decay**: A beta particle represents the loss of an electron. It might seem odd that an electron is leaving the nucleus, but that is exactly what happens in beta decay. How is this possible? A neutron is located in the nucleus. A neutron is a neutral particle. Why is a neutron neutral? It is neutral because a neutron is the combination of a proton and an electron

In essence, for beta decay, the electron is ejected from the nucleus, leaving behind the proton. Since the neutron no longer exists as a neutron, but now as a proton, the overall mass of the species does not change (remember that the mass is due to number of protons and neutrons, and while we lost a “neutron”, we kept it as a proton, so no net change in mass!). BUT, by losing the neutral particle, we gained a positive particle, which means that the total number of protons in the nucleus has changed – and it changed by one.



→ +  e

Beta decay will result in a species that has the same atomic mass, but contains one

MORE proton than itself, thus its daughter will be found one atomic number higher than itself.

Radionuclide therapy (RNT) or radiotherapy is a cancer treatment that works by utilizing beta decay. Lutetium-177 or yttrium-90 is attached to a molecule and ingested, where it travels to the cancer cells. As the radioactive atoms decay, they release beta particles and kill the nearby cancer cells.

Carbon dating is used to date artifacts, wood, and animal remains by finding the ratio of carbon-14 to carbon-12 in the object. There is always a certain amount of carbon-14 in the atmosphere, and when a plant or animal dies the carbon-14 it had in its body starts to turn into nitrogen-14 via beta decay. By using the ratio of carbon-14 to carbon-12, the approximate date of the material can be determined.



**Decay #3: Positron Decay**

**Positron decay**: A positron is the antiparticle or opposite to the beta particle. A key idea of modern physics is that every fundamental particle has a corresponding antiparticle, or a particle with the same mass but opposite charge. The positron has the same mass as a beta particle but opposite charge, therefore it has a +1 charge. It is symbolized as  e. Sometimes positron decay is referred to as positive beta decay.

Positron decay occurs through a process whereby a proton in the nucleus is converted into a neutron and a positron is expelled. This process is called pair production, which involves energy turning into matter as a high-energy photon becomes an electron and a positron simultaneously. The electron and proton bind and form a neutron, while the positron is expelled.

Because the proton becomes a neutron and stays in the nucleus, the overall mass will not change, but the charge will. In essence, the atom just “lost” a proton. Therefore the new species will have the same mass but will have one fewer proton, so its atomic number will decrease by 1.



 →  +  e

Positron emission will result in the daughter having the same atomic mass, but

will be one atomic number LOWER than the parent species

These isotopes are used in [positron emission tomography](https://en.wikipedia.org/wiki/Positron_emission_tomography) (PET Scan), a technique used for medical imaging. Note that the energy emitted depends on the isotope that is decaying; the figure of 0.96 MeV applies only to the decay of carbon-11.

The short-lived positron emitting isotopes 11C, 13N, 15O and 18F used for positron emission tomography are typically produced by proton irradiation of natural or enriched targets

