Homework 22.

Radioactivity.

We started discussing radioactivity. Radioactivity is a process of transformation of an atomic nuclei accompanied by emission of high energy particles. We learned that there are three major kinds of particles which can be emitted as a result of radioactive decay. These are α-, β- and γ-particles.

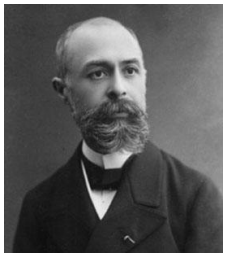
α-particle is a heavy, positively charged particle, which consists of 2 protons and 2 neutrons. After emission of a α-particle the atomic number of an element decreases by 2 and the mass number decreases by 4.

A neutron is not a stable particle and can turn into a proton. This process is called β^--decay and is accompanied by emission of an electron (so the total charge is conserved) and another particle which is called electron antineutrino. (β^+-decay with the emission of positron (anti-electron) is also possible, but we will not discuss it now). At β^--decay the atomic number increases by 1, but the mass number does not change.

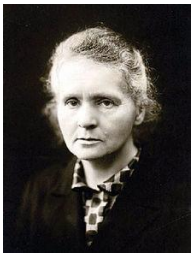
A γ-particle is a high energy particle of electromagnetic radiation. This particle has no electric charge.

The elements whose atoms experience radioactive decay are called *radioactive*, the other elements are called *stable*.

The discovery of radioactivity is associated with three names:



Henri Becquerel
(1852-1908)



Marie Skłodowska-Curie
(1867-1934)

Pierre Curie
(1859-1906)

We learned that each radioactive element is characterized by a decay constant and a half-life. Mathematically, the radioactive decay can be characterized by the following way. Let us assume that initially we have N_0 atoms of a radioactive element, say, uranium, U. As the time goes, the atoms will experience radioactive decay and will be transforming to atoms of another element. The number of Uranium atoms will be decreasing according to the expression:

$$N(t) = N_0 \cdot e^{-\frac{t}{T}} \qquad (1)$$

Here N(t) the number of uranium atoms in time t, $\boldsymbol{e}$ is a number e=2.7182818…and T is the decay constant. After time T, the initial number of radioactive atoms decreases e times. Sometimes, instead the decay constant it is more convenient to use half-life τ. Half-life is the time period after which only half of the original number of atoms is left. The decay constant is related to the half-life:

$$\tau \approx T \cdot 0.69$$

Problem:

1. Initially you have 420g of Po^{210}. The half-life of Po^{210} is 138 days. How many atoms will decay during 30 day period? Assuming that the type of the decay is α-radioactivity, what will be the resulting element?
2. Initially you have 1 gram of radium-223 with half-life of 11.43 days. How many nucleus will decay during the first second.
3. Tritium is an isotope of hydrogen having two neutrons in the nuclei. Tritium turns into helium-3 through the beta-decay, so one neutron in the tritium nucleus is converted into proton. The half-life of this process is 12.32 years. Initially we have 0.0001g of tritium. How much of it will be left after 3 years?