Homework 26

**Radioactive transformations of elements.**

We have recently discussed one of the effects of β- and α- radioactivity – transformations of chemical elements. This was demonstrated by Ernest Rutherford as early as in 1902. This fact was not readily accepted by the community of chemists, but strong experimental evidence made the statement undeniable.

First of all it turned out that the β-rays are the electrons emitted by atomic nuclei. But if this is so, than the positive charge of the nucleus is increased after the emission of an electron (due to charge conservation) and the atomic number has to be increased by 1. This is strange, for a first glance – we know that there are no electrons in the atomic nucleus, there are just protons and neutrons. But it turns out that protons and neutrons can transform into each other by emission of electron or positron. The latter is anti-electron, particle with the mass and absolute value of charge equal to these of the electron, but having positive charge. These transformation processes are called "β-decay". There is one more neutral particle which is produced in β-decay in addition to electron (positron). It is "electron neutrino" in case of proton transformation or "electron anti-neutrino" in case of neutron decay. Symbolically the transformation of the elements in b-decay can be compactly written as follows:

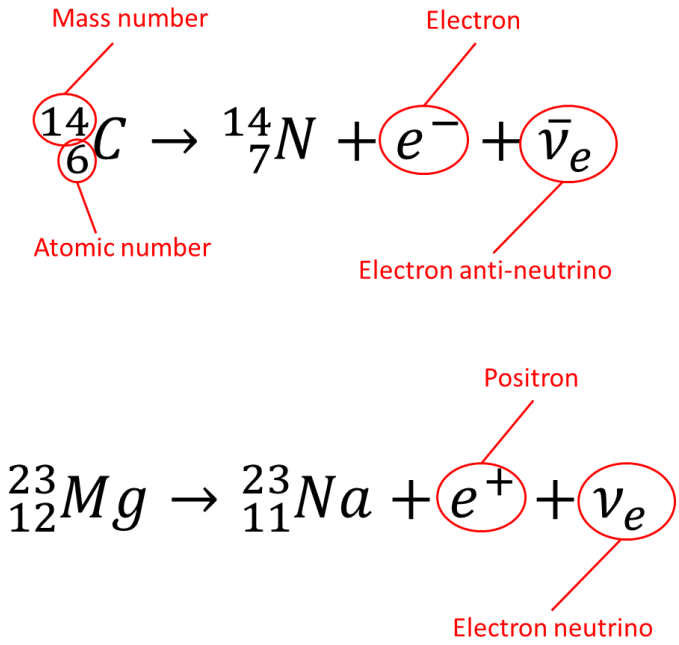


Figure 1. Examples of b-decay.

As we can see in case of b-decay the mass number does not change, but the atomic number changes by 1.

The first equation shown in Figure 1 is the base of the radiocarbon dating. Unstable isotope of carbon - $^{14}_{6}C$, also called carbon-14 is produced in upper atmosphere exposed to cosmic rays. Then,

carbon-14 is absorbed by plants in the process of photosynthesis and by animals eating the plants. After the plant or animal dies it stops absorbing carbon 14 and its amount in the plant's body gradually decreases following the exponential law which we discussed last time. The half-life of carbon 14 is 5730 years. So, by measuring the ratio of concentration of carbon-14 to this of "normal" carbon-12 in the remains of an ancient plant or animal it is possible to estimate how long ago the plant or animal died. Willard Libby received 1960 Nobel Prize in Chemistry for the development of radiocarbon dating method.

Another radioactivity process which leads to the transformations of chemical elements is α-decay. In the process of α-decay, atomic nucleus emits an α-particle, consisting of 2 protons and 2 neutrons. In this process, the atomic number decreases by 2 and the mass number decreases by 4.

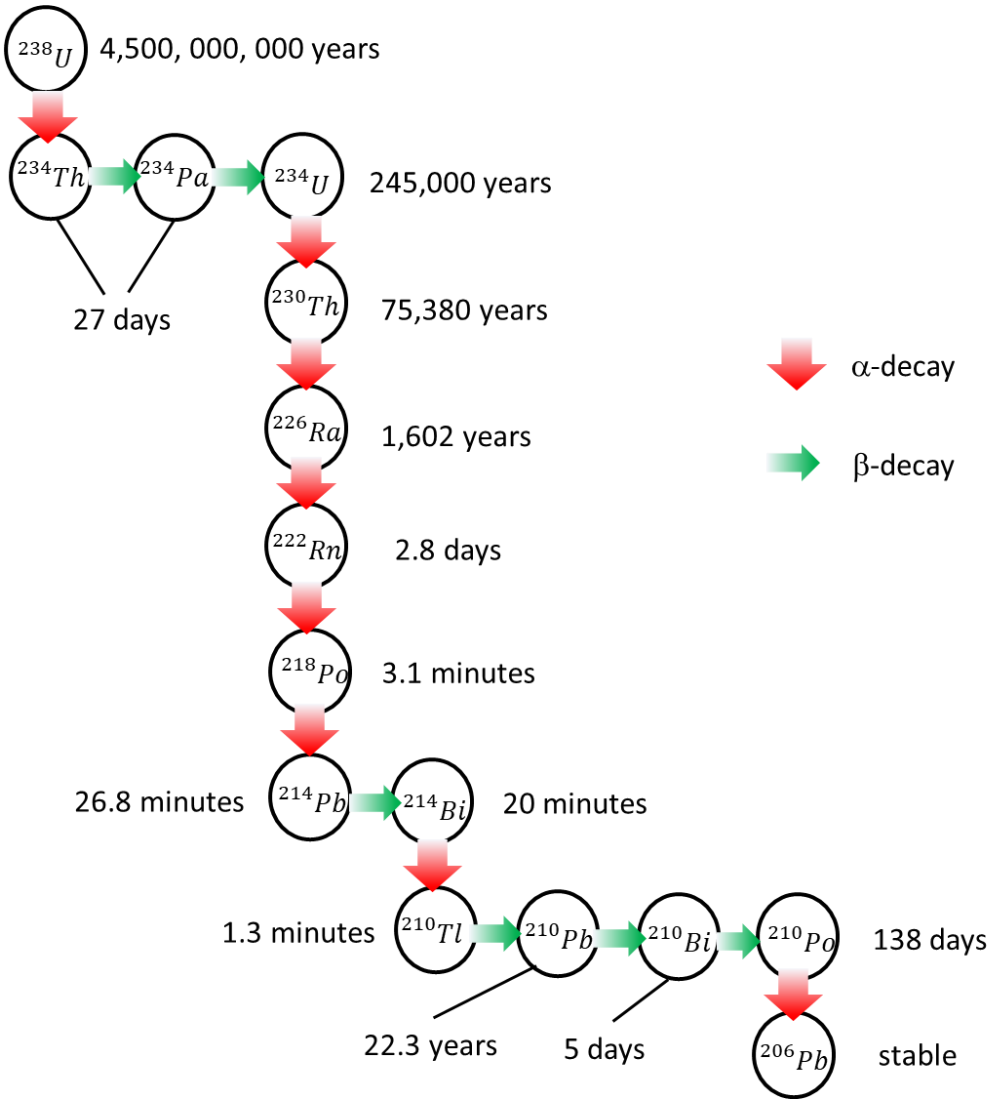


Figure 2. Uranium-238 decay chain with the element half-lifes.

The unstable elements undergo a chain of transformations through α- and β-decays. There are several decay chains with different "starting" elements such as uranium-238, thorium-232 or uranium-235. One of this chain (uranium-235) is shown in Figure 2.

Another examples of radioactive decay is *nuclear fission* and *nuclear fusion*. In nuclear fission, and unstable isotope splits into several "parts" and releases large energy. Example of nuclear fission is:

$$^{236}_{92}U \rightarrow {}^{141}_{56}Ba + {}^{92}_{36}Kr + 3n\ (3\ neutrons)$$

In a nuclear fusion process, nuclei "stick" together and form a new nucleus. The example is transformation of hydrogen into the helium in the core of the star.

Problem:

1. The dream of alchemists was making gold out of lead. Suggest a hypothetical radioactive transformation chain which could "make" it. (An isotope of gold will work as the result).