Homework 19

Radioactive decay.

We learned that the nuclei of heavy elements are unstable and can be transformed through radioactive decay. As result of radioactive decay the nucleus loses energy and emits (depending of the process) alpha-particles, electrons, positrons and gamma-rays. We also learned that the time dependence of the radioactive decay rate is unusual. When we speak about a rate we usually keep in mind "events per unit time, for example, per second". Time dependence of the radioactive decay does not obey a constant rate law. In other words, the number of nuclei decaying per unit time is decreasing with time. If, during the first minute, 10 nuclei decayed, then during the second minute the number of the decayed nuclei will be less – say, 6 or 7.

According to the law of radioactive decay a *fixed fraction* of the initial number of nuclei decays per unit time. It means that if we initially have, say, 16 nucleus, in a certain time half of the them (8) will be left,. Then, after same time there will be 4 nuclei, etc. The time required to decay half of the initial number of atoms is called half-life and denoted as $t_{1/2}$ Mathematically the law of radioactive decay can be written as:

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

Here $N(t)$ is the number of nuclei at time t, N_0 is the initial number of nuclei, $e \approx$ 2.718281828 is so-called Euler's number or Napier constant , T is the time constant of the radioactive decay. T depends on the type of the nuclei and the decay process. In time T, an initial number of the nuclei decreases e times. The time constant and half-life are related through the expression:

$$t_{1/2} = 0.69 \cdot T$$

For example half-life of uranium-238 is 4.468 billion years, uranium-235 – about 0.7 billion years.

Problem:

1. Initially you have 1 gram of radium-223 with half-life of 11.43 days. How many nuclei will decay during the first second.

2. 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?