УДК 539.17=111

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Harnessing the Nucleus

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Look at the home in Figure1. You can also see a large mound of coal. This amount of fuel will supply the energy needs of this home for about three months. Next to the coal you see a small pellet of uranium about the size of a jelly bean. This amount of uranium will also run the house for about three months. How can this amount of uranium produce so much energy? Let us try to answer this question.

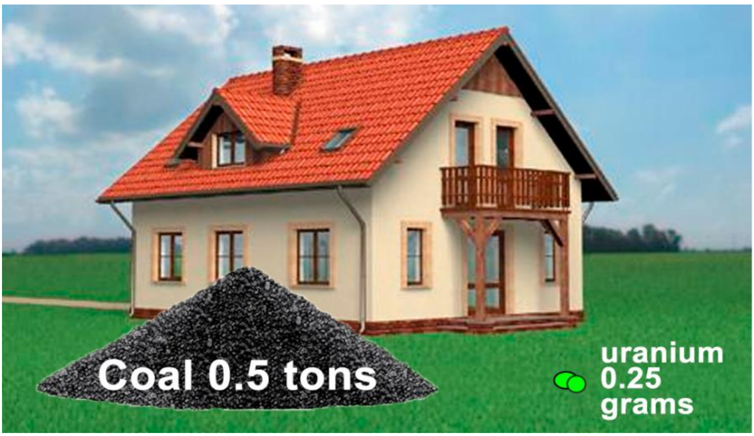

Fig. 1 – Fuels Supply Energy

You have seen that natural and synthetic radioactive elements are unstable. Their nuclei decay, emitting radiation, until they change into stable elements. Decay happens continuously. It is a spontaneous nuclear reaction. That is, it occurs naturally, on its own. However, some nuclear reactions can be induced. If you have played marbles, you have set up a model of induced radioactive decay. If you shoot one marble into a pack of marbles, you can split the pack apart. But you have to aim the shooter marble carefully.

A similar situation can occur with radioactive nuclei. For example, uranium-235 (U-235) can be made to split apart. The “shooter” in this case is a neutron. When a slow-moving neutron is shot into a U-235 atom, it enters the nucleus. The latter becomes unstable and immediately splits apart into two smaller nuclei. Also, three neutrons are emitted as products of the reaction. The nuclear reaction is an example of nuclear fission. Nuclear fission is the splitting of a nucleus with a large mass into two nuclei with smaller masses [1].

The first successful nuclear fission test took place in 1939. A huge amount of energy was released. Scientists were curious about where so much energy came from. Later they calculated the total mass of the barium, krypton, and the neutrons. This mass was less than the mass of the U-235 plus the initial neutron. What happened to the missing mass?

Albert Einstein had provided the answer to the question of missing mass years before the first fission test. In the early 1900s he predicted that in some reactions mass could be changed into energy. This prediction was later proven to be true. His famous equation $E = mc^2$ is now used to calculate the energy produced in nuclear reactions [2]. What happens after a nucleus splits? Once again, marbles can be used as a model. When the shooter in Figure 2 hits the first pack of marbles, the pack splits. However, some of the marbles from the pack now become shooters for the other packs. This process continues until there are no more unsplit packs.

The fission of U-235 nuclei follows a pattern similar to that of the marbles. In splitting apart, the U-235 nucleus emits three neutrons. These neutrons then enter three other U-235 nuclei. They, in turn, split. Now there are nine neutrons. These nine then enter nine other U-235 nuclei, and the process continues. The process described above is a chain reaction. A chain reaction is one in which some of the products of the reaction cause the reaction to keep going [3].

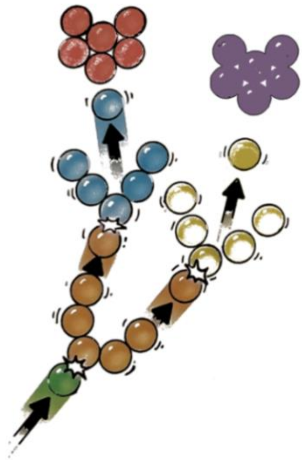

Fig. 2 – Collisions in a Chain Reaction

References:

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3. Nuclear Chain Reactions [Electronic resource]. – Mode of access: https://www.atomicarchive.com/science/fission/chain-reactions.html. – Date of access: 13.03.2022.