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A Lecture on Nuclear Physics in Primary School

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ABSTRACT

I am going to propose the contents of a lecture on nuclear physics and radioactivity in primary school.

Contemporary technology, medicine and science exploit intensively the discovered knowledge about processes in atoms and in a nucleus. Mankind has gained huge profit from peaceful applications of nuclear reactions and ionizing radiation. We use the products of nuclear industry every day. But about half of the school population never hears a professional explanation about what is going on in nuclear power plants. Only on some secondary schools students learn about nuclear physics. The lack of knowledge about nuclear processes is the main reason why people show great fear when hearing the words: radiation, radioactivity, nuclear, etc.

At last it is now time to give some fundamental lessons on nuclear physics and radioactivity also to pupils in primary school. From my four-year teaching experience in primary school I am suggesting a programme of lectures on nuclear physics and radioactivity. At the end of the lessons we would visit the Krško Nuclear Power Plant or the Nuclear Training Centre Milan Čopič. This could be included in the so called natural science day. Pupils come from the eight class (14 years old) of primary school and have no problems following the explanation.

1 INTRODUCTION

The Slovenian primary schools curriculum does not anticipate dealing with the fundamental findings of nuclear physics and its related radioactivity. More than 100 years have passed since the discovery of radioactivity. Scientists have discovered and explained all of the most important laws of nuclear physics. Despite undisputed benefits, which are brought by the use of nuclear technology and radioactivity, and despite the rising amount of acquired electric power in nuclear plants, teaching of physics does not treat what is going on in the nucleus of an atom. Most of the pupils in our educational system finish their schooling without ever hearing an expert's explanation on nucleus structure and about nuclear reactions, which take place in stars or in nuclear reactors. In my opinion, it is time that we teach the young the basics of nuclear physics and radioactivity. Fundamental findings of nuclear physics are to be taught in primary school.

Primary school pupils should start getting some knowledge with describing some concrete examples of use of nuclear energy and radioactive radiation in everyday life. The subject matter should be presented interestingly, without complicated formulas and theory, which is difficult to comprehend. According to school's possibilities, some simple experimental tasks could also be carried out.

2 THEORY

I think it is appropriate to start the explanation with a description of how a nuclear power plant works. Nuclear power plants are a fact and are a significant option for the world needs of electricity in the 21st century. There are around 450 nuclear power plants in the world. They provide approximately 17% of world energy consumption. Pupils have heard about the Slovenian Nuclear power plant in Krško, therefore they will be 'familiar' with the subject.

The lecture should present the following topics:

- How do we get electricity?
- Basics of energy release during nuclear fission.
- Ionizing radiation and radiation protection.

The contents of individual topics are dealt with in the supplement.

I recommend that dealing with nuclear power plant should be combined with a visit of the Nuclear power plant in Krško or with the Nuclear Training Centre Milan Čopič in Ljubljana. Both of the institutions offer a 2-hour-long visit, which consists of an introduction in the form of a short lecture and of a visit of the exhibition. In the Nuclear power plant in Krško the group is taken around the secured area by bus. The main buildings of the nuclear power plant are shown. In the Nuclear Training Centre Milan Čopič pupils carry out some practical measurements of radioactive substance and ionizing radiation.

Pupils are supposed to learn about the basic detections of radioactive radiation through an experimental exercise: The search of radioactive source. We need a low radioactive source (uranium ore is appropriate) and an instrument, which detects radioactive gamma radiation. The radioactive source is hidden in the room. Pupils look for the source with the instrument on the basis of the increase of the gamma radiation. Usually the source is found in 10 minutes.

Also some clear visual animations of radioactive decay and the measurement of radioactivity on a CD-ROM prepared by Marjan Hribar and Jože Pahor could be included into classes.

3 CONCLUSIONS

The described approach of dealing with nuclear physics and radioactive topics has been carried out in the eighth grade of primary school for four years. The topic is covered in two school lessons before the visit of the Nuclear power plant in Krško or the Nuclear Training Centre Milan Čopič. Together with the explanation I draw a picture on the blackboard and use the overhead projector. I pay attention that the knowledge already gained is gradually upgraded. Pupils usually do not have any problems with understanding of the subject matter. They accept the explanation in the same way as they accept the explanation of other physical laws. The experiment and consolidation of the knowledge need another hour. I conduct the experiment only if the pupils show enough interest for the topic. I borrow the instruments at my acquaintances, experts. The visit of the Nuclear power plant or the Nuclear Training Centre Milan Čopič is organised within a natural science day at the beginning of the school year. I distribute sheets with questions on the bus just before the visit. Immediately after the visit I gather these sheets and mark them. The answers to the questions show how the pupils understood the subject. Pupils have always returned enthusiastic form the field trip. They have come across high technology and the latest findings, which have been discovered recently. Pupils do not feel any fear of the unseen radioactivity. Also their parents and some of the teachers have lost the original fear of radioactive radiation.

SUPPLEMENT

The contents of the lecture

1. How do we get electricity?

An electric generator of a power plant is converting mechanical energy of rotating **turbine** into electricity. According to energy, which rotates the turbine we distinguish: hydro plants, wind power plants, fossil fuel power plants, nuclear power plants, ...

Construction of the nuclear power plant is very similar to the conventional fossil fuel power plant. The steam from steam **generators** rotates the steam **turbine**, which spins the electric generator. Under the turbine there is a **condenser** where steam is cooled to water. The main difference is the source of the heat used to create steam. Instead of burning out coal or oil we get heat in the nuclear power plant by a **nuclear fission** of uranium-235 or plutonium-239.

2. Basics of energy release during nuclear fission

Atoms consist of a relative massive, **positively charged nucleus**, around which negatively charged **electrons** move. The nucleus of U-235 has 92 positively charged **protons** and 143 neutral **neutrons,** which are bonded together with **strong nuclear force**. We induce fission by adding energy to nuclei. We bombard U-235 with slow neutrons. As soon as the uranium nuclei captures the neutron, it **splits up** into two nuclei of lighter elements travelling in opposite directions with tremendous speed (kinetic energy). A waste amount of energy is released, in the form of heat and gamma radiation, when a single atom splits. The energy released by a single fission comes from the fact that the fission products weigh less than the original U-235 atom. The difference in weight is converted directly to energy at a rate governed by the Einstein`s famous equation $\mathbf{E = m.c^2}$. The released energy in the uranium core of the nuclear reactor heats water and turns it to steam. The water acts as a coolant.

During the fission two or three neutrons are liberated from the uranium nucleus. They trigger next fission if there are other U-235 atoms nearby. We get the so called **nuclear chain reaction**. Three things could happen:

- if, on average, exactly one of the free neutrons from each fission hits another U-235 nucleus and causes its split, then the mass of uranium is said to be **critical**. The mass of uranium will exist at a stable temperature. A nuclear reactor must be maintained in a critical state. This makes a constant heat source.
- if, on average, less than one of the free neutrons hits another U-235 atom, then the mass is **subcritical**. Eventually, induced fission will end in the mass.
- if, on average, more than one of the free neutrons hits another U-235 atom, then the mass is **supercritical**. It will heat up. For a nuclear bomb the mass is very supercritical that many U-235 or Pu-239 atoms split in a microsecond.

To control the rate of the nuclear reaction in the core we use **control rods** made of a material that absorbs neutrons. By putting control rods completely into the core operators shut down the nuclear reaction.

3. Ionizing radiation and radiation protection

Ionizing radiation has enough energy to eject one or more electrons from the atoms or molecules in the irradiated medium. They can change chemical bonds.

Nuclei of lighter elements originated from the splitting process of U-235 are **unstable**. They decay spontaneously emitting ionizing radiations. There are three types of radiation:

Alpha radiation corresponds to the emission of a helium nucleus
Beta radiation corresponds to the emission of an electron or positron
Gamma radiation corresponds to the emission of an electromagnetic radiation

Nuclear reactors are not the only source of ionizing radiation. Since the beginning of the Universe, probably some fifteen thousand million years ago, radioactive atoms have decayed. The so called **natural radioactivity** is present everywhere: in soil, in water, in air, in food, and also inside a human body. The radiations come also from the cosmos as **cosmic rays**.

The ionizing radiation can damage living cells. If the number of damaged cells is small, they will be replaced, and there will be no harmful effects. If enough cells in an organ or tissue are killed, there will be a loss of organ function. The final result will be death.

The best protection against the harmful effects is to avoid the radiation. Do not go to a radiation area! If a person has to go to the radiation area, they should spend there as short time as possible and be properly shielded against the specific radiation.

Since the penetrating power of the various types of radiation is different, radiation protection techniques must be specifically adapted to each one:

- alpha radiation can be stopped by a sheet of paper or by 5 cm thick of air.
- beta radiation can be stopped by aluminium foil or a plate of glass or by clothes or some meter of air. Alpha and beta emitters are most dangerous through inhalation and ingestion.
- gamma radiation can be stopped or attenuated by significant thickness of concrete, or more than 10 cm thick layer of lead or by 1 m thick layer of water.

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