Lectures of Elementary particles physics

Masters Students

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Lecture one

Ch-1/Introduction

Ref. :1- Atomic and nuclear physics

2nd Ed. Talittlefield

- 2-Introductory nuclear physics
- Kenneth S .Krane

1.1\ Atoms, Nuclei and Particles
1.2\ Particle Names and the Greek Alphabet
1.3\ Conservation Laws
1.4\Elementary particles model

Introduction

The twentieth century has seen an enormous progress in physics.
The fundamental physics of the first half of that century was dominated by the theory of relativity, Einstein's theory of gravitation, and the theory of quantum mechanics. The second half of the century saw the rise of elementary particle physics.
In other branches of physics much progress was made also, but in a sense developments such as the discovery and theory of superconductivity are developments in width, not in depth. They do not affect in any way our understanding of the fundamental laws of Nature.
Max Planck founder of quantum physics. In 1900 he conceived the idea of quantized energy, introducing what is now called Planck's constant, one that sets the scale for all quantum phenomena. In 1918 he received the Nobel prize in physics. In recognition of the services he rendered to the advancement of Physics by his discovery of energy quanta." Planck was one of the first to recognize Einstein's work, in particular the theory of relativity

1.1 \ Atoms, Nuclei and Particles

All matter is made up from molecules, and molecules are bound states of atoms. For example, water consists of water molecules which are bound states of one oxygen atom and two hydrogen atoms. This state of affairs is reflected in the chemical formula H_2O.

There are 92 different atoms seen in nature (element 43, technetium, is not occurring in nature, but it has been man-made). Atoms have a nucleus, and electrons are orbiting around these nuclei. The size of the atoms (the size of the outer orbit of the electrons) is of the order of 1/100 000 000 cm, the nucleus is 100 000 times smaller. The atom is therefore largely empty. Compare this: suppose the nucleus is something like a tennis ball (about 2.5 inch or 6.35 cm diameter). Then the first electron circles at a distance of about 6.35 km (4 miles). It was Rutherford, in 1911, who discovered that the atom was largely empty by shooting heavy particles (α particles, emanating from certain radioactive materials) at nuclei. These relatively heavy particles ignored the very light circling electrons much like a billiard ball would not

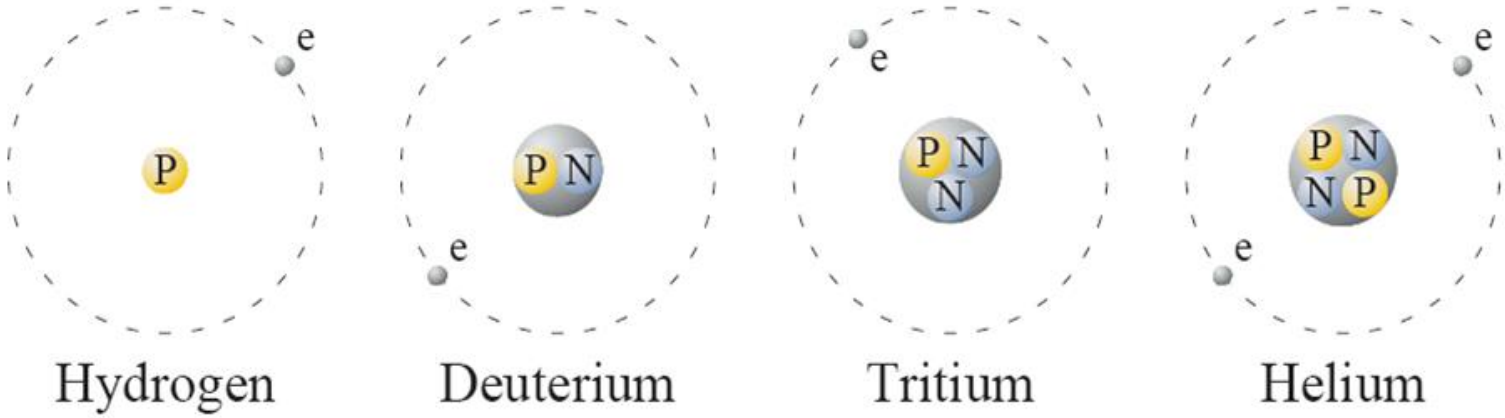
notice a speck of dust. So they scattered only on the nucleus. without going into detail we may mention that Rutherford actually succeeded in estimating the size of the nucleus.

Niels Bohr in 1913 proposed the model of the atom,containing a nucleus orbited by electrons. In the period thereafter he was the key figure guiding the theoretical development of quantum mechanics. While Heisenberg, Schrö., Dirac and Born invented the actual mathematics, he took it upon himself to develop the physical interpretation of these new and spooky theories. Einstein never really accepted it and first raised objections at the Solvay conference of 1927. This led to the famous Bohr-Einstein discussions, where the final word (at the 1930 Solvay conference) was Bohr's, answering Einstein using arguments from Einstein's own theory of gravitation.Even if Bohr had the last word, Einstein never wavered from his point of view. It should be mentioned that Bohr started his work leading to his model at Manchester, where Rutherford provided much inspiration. Bohr's famous trilogy of 1913, explaining many facts, in particular certain spectral lines of hydrogen (Balmer series), may be considered (in Pais' words) the first triumph of quantum dynamics.

What are nuclear particles?

The nucleus contains ***protons*** and ***neutrons***, also called ***nucleons***. Both protons and neutrons bound together by the strong force. The proton has an electric charge of +1,but the neutron is electrically neutral.

The number of electrons in an atom equals the number of protons in the nucleus, and consequently atoms are electrically neutral. It is possible to knock one or more electrons off an atom; the remainder is no longer electrically neutral, but has a positive charge as there is then an excess number of protons. Such an object is called an **ion**, and the process of knocking off one or more electrons is called **ionization**. For example electric discharges through the air do that, they ionize the air.



The lowest mass atom is the ***hydrogen*** atom, with 1 electron and a nucleus consisting of just 1 proton. The nucleus of heavy hydrogen, called ***deuterium***, has an extra neutron. If both hydrogen atoms in a water molecule are deuterium atoms called "***heavy water***". ***Tritium*** is hydrogen with 2 extra neutrons in the nucleus. Helium is the next element: 2 electrons and a nucleus containing 4 nucleons, i.e. 2 protons and 2 neutrons.

Nuclear physics is that branch of science that covers the study of atomic nuclei. The nuclear experimenter shoots electrons or other projectiles into various nuclei in order to find out what the precise structure of these nuclei is. He is not particularly interested in the structure of the proton or neutron, although nowadays the boundary between nuclear physics and elementary particle physics is becoming blurred.

Ernest Rutherford investigated and classified radioactivity. He did the first experiments exhibiting the existence of a nucleus. In 1908 he received the Nobel prize in chemistry, "for his investigations into the disintegration of the elements, and the chemistry of radioactive substances". He is surely one of the rarest breed of people, doing his most important work after he received the Nobel prize. I am referring here to the scattering of alpha particles from nuclei. The actual experiment was done by Geiger and Marsden, under the constant influence of Rutherford. Later, Rutherford produced the relevant theory, which is why we speak today of Rutherford scattering. He was the first to understand that there is something peculiar about radioactivity.

Rutherford was a native of New Zealand. He was knighted in 1914 and later became Lord Rutherford of Nelson. His importance goes beyond his own experimental work. His laboratory, the Cavendish (built by Maxwell), was a hotbed of excellent physicists. Chadwick discovered the neutron there (Nobel prize 1935) and in 1932 Cockcroft and Walton (Nobel prize 1951) constructed a 700 000 Volt generator to make the first proton accelerator. Some laboratory!