STAT

Concerning Atomic Energy and the Possibilities of its Utilization for Control of the Weather

Przeglad Meteorologiczny i Hydrologiczny, No. 1, pages 40-57; Jerzy Rayski; Warsaw: April 1948.

STAT

CONCERNING ATOMIC ENERGY AND THE POSSIBILITIES OF ITS UTILIZATION FOR CONTROL OF THE WEATHER

Jerzy Rayski

(The author obtained his doctor's degree in the field of physics from the University of Warsaw. At present, he is a lecturer in theoretical physics at the University named after Nikolaj Kopernik in Torun. Editor's note.)

At the beginning of this series of articles concerning atomic energy, I should like to acquaint my readers with several basic properties of atoms. What is an atom? As we all know, an atom is the basic unit of which the material world consists. Atoms have unbelievably small dimensions. Let us write the number one followed by 21 zeroes: that is the amount of atoms within one gram of any heavy element. If we could extrude one gram of gold into a thread so thin that all of the atoms therein could be placed one following another, we would obtain a thread so thin and so long that it would be able to go around the world several times. This example well illustrates the quantity and minute dimensions of atoms. Atoms, however, are not the smallest creations in nature. Each atom consists of a nucleus and electrons which move around the latter. An atom is small, but its nucleus is even smaller. If we were to enlarge the whole atom in our minds to the size of a ball having a diameter of ten kilometers, the nucleus of such an atom would only be the size of an apple. Almost the total mass of the atom is in the nucleus. We can thus see that even the densest matter is only apparently dense. In reality, matter consists of a vacuum throughout which there are inconceivably small yet massive points - the nuclei of atoms. Even atomic nuclei are not indivisible among the elements of the physical world. Nuclei are composite units and are built of two types of particles: protons and neutrons, which are considered today as being the most basic particles. Their mass is almost equivalent, but they do differ in their electrical charges. A proton has a positive charge of the same quantity as the negative charge of the electron. The neutron, as its name indicates, has no charge at all. The chemical properties of the atom depend upon the size of the electrical charge in the nucleus, that is upon the number of protons within the nucleus. Hydrogen atoms are the most simple and the lightest: the nucleus here consists simply of a single proton. Next in line are helium atoms, having two protons in their nuclei; lithium atoms - three protons each, etc., up to the heaviest of elements - uranium in the nucleus of which there are 92 protons. Lately, two new elements have been artificially created: neptunium and plutonium, having 93 and 94 protons respectively. The kind of element that we are dealing with depends upon the number of protons in the nucleus. On the other hand, neutrons do not influence to any great extent the chemical properties of the atom. There are known to exist in nature, for example, atoms that have in their nucleus apart from 17 protons also 18 or 20 neutrons. The one as well as the other are chlorine atoms, which is decided by the 17 protons. The one nucleus is a little lighter and the other somewhat heavier, since they contain two additional neutrons. Such atoms, which differ only in weight, are called isotopes. As was mentioned above, the mass of the proton does not differ substantially from the mass of the neutron. In view of this, a nucleus consisting for instance of 7 protons and 8 neutrons - in total 15 basic particles with equal masses - should be 15 times heavier than the nucleus of hydrogen which consists of only one particle. It appears, however, that this is only true in approximation. The weight of a nucleus, consisting of a certain number of particles, is not equal but somewhat smaller than the total mass of these particles taken individually. This is a serious paradox and a riddle which could not be solved by traditional methods of old physics. Classical physics taught that mass is permanent and unchange-

Declassified in Part - Sanitized Copy Approved for Release 2012/05/16 : CIA-RDP82-00039R000100160042-8

able with reference to the properties of matter. According to the laws of old physics, the total mass should simply be the sum of the individual particles, independently of the fact whether the particles are gathered within a narrow area or are far from one another. In the meanwhile, protons and neutrons as components of the nucleus are lighter than the protons and neutrons in independent existence.

Einstein was able to explain this paradox. In his famous theory of relativity, he destroyed the old postulate on the stability of mass. According to the theory of relativity, not only matter is massive and heavy. The same pertains to energy in all of its manifestations. A certain amount of mass and a certain weight is connected with any type of energy, in view of which the mass of the particles of matter must undergo a change when the energy changes. The mass of any particle must be enlarged if we add energy and on the contrary - a particle becomes lighter if we take energy away from it.

Somebody once used an appropriate comparison by saying that mass and energy are like two different rates of exchange. ($E = m\,c^2$. This is Einstein's equation which permits us to compute the "exchange rate" of mass to energy. E means energy, m stands for mass, whereas c^2 is the velocity of light raised to the second power.) This rate of exchange is disadvantageous for energy: energy is a weak exchange currency, mass a strong currency. Huge quantities of energy must be traded for a minute amount of mass. Therefore, even during very large transformations of energy, mass changes only insignificantly. This is the explanation for the fact that physics experts were up to recently under the illusion that mass is unchangeable.

PART I

After this excursion into the field of theory, let us return to our topic - the matter of the atom. As we said before, the atomic nucleus manifests a certain, however small, loss of mass. In line with the theory of relativity, this so-called defect in mass points toward the fact that a portion of energy weighing the same as the loss in mass has freed itself from the group of protons contained in the nucleus. Even though this loss of mass is small, in itself, the quantity of energy freed must be considerable as is indicated by a computation of the exchange rate of mass to energy. Accurate measurements of atomic masses have proven that medium-weight elements, situated more or less in the middle between the lightest hydrogen and the heaviest uranium, possess the greatest mass defect. In view of this, an important possibility arises: namely, we could free atomic energy if we could do one of the following two things: either build heavy elements from light ones, for instance helium from ~~xxxxxxxx~~ hydrogen through synthesis since the former is four times heavier than the latter; or the opposite, if we could break up the heaviest elements like uranium into lighter ones. In both of these cases, elements would arise with a larger defect in mass. This means that the atomic energy would have to be liberated. The second of the above discussed possibilities has already been realized by humanity in the form of the atomic bomb. On the other hand, man has not been able to realize the second possixbility.

It should be mentioned, however, that nature itself realizes to a certain degree both of these possibilities. On the one hand, we are all acquainted with the natural formation of rays discovered by Maria Curie Sklodowska. She proved that some of the heaviest atoms, such as uranium, thorium, actinium and radium, are not stable and ~~fall apart of~~ decay ~~their own accord~~ spontaneously. During this process, they give off considerable amounts of energy and are finally transformed into lighter lead. On the other hand, there is no doubt today that transformations of the lightest atoms into heavier ones take place on a large scale in nature. Scientists have been intrigued for a long time by the source of the conti-

Declassified in Part - Sanitized Copy Approved for Release 2012/05/16 : CIA-RDP82-00039R000100160042-8

nuous radiation of the sun and the stars. According to the latest theories, the process of synthesizing hydrogen atoms into helium atoms is constantly taking place on the sun and the stars. If not for this nuclear process, the sun would have long ago stopped shining and would not have been able to radiate for billions of years. It is only recently that we have gained the knowledge to what we owe the sun's heat and indirectly our life - atomic energy.

We can, therefore, say briefly that there exist two ways by which it is possible to free atomic energy. One of these methods is based upon the transformation of the heaviest nucleuses into medium heavy ones by splitting; the other is based on the transformation of the lightest nucleuses into heavier ones by means of synthesis. Both of these processes take place all by themselves in nature. The known phenomenon of the radiation of radium is based on the breaking down of heavier nucleuses into lighter ones which are fragments. It is the process of synthesis of the lightest nuclei into heavier ones that gives us the sun's energy, without which no life would be possible.

These natural sources of atomic energy would not suffice for man, however. Man desired to take and active part in the process of transforming the elements and dared to liberate atomic energy on his own. The first man to achieve the splitting of an atom was the Englishman Rutherford. This was in 1919. Yet many people understood the importance of this event. The press carried a modest note of laconic content which said nothing to the layman: A nitrogen atom was split and transformed into an atom of oxygen by means of bombarding with alpha particles. The question arises as to how exactly is a nitrogen atom split. In general, the process can be described as follows: an alpha particle, which is light in comparison with the nucleus of nitrogen and which consists of two protons and two neutrons, collides with the nucleus and breaks away an even lighter particle from the latter - namely one proton. The alpha particle itself remains imbedded in the nucleus forever, whereas the proton flies away in the form of a small splinter. What remains after the breaking away of the proton and the imbedding of the alpha particle is no longer the nucleus of nitrogen but the nucleus of universally known oxygen.

Beginning with this first case of splitting the atom and up to 1938, many other possibilities for splitting atomic nucleuses were discovered for different elements. In each case, the process had a similar procedure: the atoms were bombarded by light projectiles. In case of a direct hit, the latter changed the nucleus of the given element into a nucleus of another element which was not much different in mass and charge from the original nucleus. The projectile which imbedded itself in the nucleus as well as the splinter were both light and possessed a small electric charge in comparison to the nucleus. We can thus see that the word "splitting" is not altogether justified and accurate. The atom does not fall into pieces like a broken flower vase but is transformed ~~xxxx~~ by means of imbedding the projectile or by the splintering off of a small fragment.

Experts on physics have been long aware of the tremendous resources of energy hidden and sleeping in matter. Abstract computations, based on the theory of relativity mentioned above, pointed to this fact. However, none of the experiments conducted between 1919 and 1938 in connection with splitting the atom ever confirmed the hopes held for obtaining any considerable amount of usable energy from this process. It appeared that the amount of energy expended for the projectiles used in splitting atoms was larger than the energy obtained from the process itself. The reason for this was that the nucleus of the atom has extremely small dimensions and that to hit the nucleus - thousands of projectiles are necessary. Even when the bombardded atoms are as dense as possible, their nucleuses are at relatively long distances from one another. As a result of this, by far the great majority of the projectiles go into a vacuum and do not hit any of the nucleuses, and their energy is wasted. We can see that splitting the atom in these days was not an economical process. Investments had to be greater than incomes, and the balance was always negative. This fact made many scientists doubt in the possibility of any energy for practical purposes by this means. When Rutherford himself was asked about the possibilities of utilizing atomic energy, a few years after he had split the first atom, he expressed doubt.

PART II

The state of affairs remained thus until 1938, when the German physicist Otto Hahn noticed the appearance of traces of barium while he was conducting experiments at splitting uranium by bombarding it with neutrons. He did not think at the beginning that barium could be a product of the disintegration of uranium, because the former is about twice as light as the latter. As we mentioned in our discussion previously, all up to then known examples of splitting the atom gave as a result new atoms which differed from the original one by only a small percentage in weight and charge.

The matter was, therefore, a riddle. The supposition was arrived at that this time the splitting had been complete and that the atom had been split into two approximately equal parts, one of which was barium. The Viennese physicist Liza Meitner, who fled from Germany to Copenhagen, named the process of splitting the atom by the word "fission." This term had been used previously in biological sciences to express the process of splintering of cells by means of division.

Notified indirectly through Copenhagen of the new discovery, American physicists immediately began experiments and soon corroborated in whole the new hypothesis. It appeared that the bombarded uranium atom in fact does break up into two approximately equal parts which are the nucleuses of such atomic elements as barium and crypton.

In further experiments, it appeared that during the breaking up of the nucleus of uranium - apart from the two medium heavy nucleuses - there are also formed additional splinters in the form of several neutrons. This was a fact of tremendous importance, because neutrons are the projectiles which provoke "fission." In view of this discovery the thought immediately arose that - under certain conditions - the once started process of breaking up uranium could start a chain reaction:

The first neutron cracking the nucleus of uranium causes the splintering off of several new neutrons which could then crack other uranium nucleuses; their splinters in the form of further neutrons would crack further uranium atoms and so forth. In such a way, the process of cracking uranium nucleuses could widen like a chain reaction ever farther. Since one neutron cracking a nucleus causes the appearance of several neutrons, the process of disintegration could gain tremendous concentration until the disintegration of almost all of the collected number of uranium atoms. Since, however, each individual disintegration of a uranium atom frees a considerable portion of energy - a disintegration of the total amount of uranium could liberate summed up a huge amount of energy. One kilogram of uranium, brought to disintegration by the chain reaction, would give as much energy as ten thousand tons of the most potent explosive material.

Tempted by such fantastic perspectives, physicists began intensive work toward producing these chain reactions. In the mean while, the Second World War was taking on ever wider dimensions. In view of the importance which atomic bombs could have upon the further course of the war, the governments of the belligerents issued strict orders against the publication of information concerning the

the splitting of the uranium atom. Subsequent experiments, up to the use of the first bomb against Japan, were covered with secrecy. It was only after dropping the first bomb on Hiroshima that the United States' Government published certain details concerning experiments with atomic energy. We will now discuss these.

Let us say that we have at our disposal a piece of uranium and one neutron. This neutron on hitting any one uranium nucleus will cause an explosion and free at least two further neutrons. The latter may hit other uranium nuclei, and as a result of their explosion two times two which is four neutrons will be formed. These four new neutrons may split the next nuclei and liberate 8 neutrons, etc. We see that by this means the number of neutrons grows tremendously and ever more uranium nuclei undergo splitting. This type of process is called a chain reaction. After proceeding through a series of links in such a chain, the total energy liberated from the disintegration of 1 kilogram of uranium, for example, will equal the energy of approximately 10,000 tons of the strongest of the ordinary explosive materials - so-called TNT.

PART III

Up to now, I have presented the whole matter as simply as possible. My aim was to explain the principle of liberating energy by the method of the chain reaction. In reality, this phenomenon is a little more complicated. It appeared first of all that only one among the uranium isotopes undergoes splitting by neutrons. This isotope is called U-235. Neutral uranium, obtained from the ore, consists of two isotopes - a heavier and a lighter one. The nucleus of the lighter one consists of a total of 235 protons and neutrons; the nucleus of the heavier one possesses three neutrons more. Such is the origin of the names U-235 and U-238. The heavier uranium 238 does not undergo splitting and does not lead to a chain reaction. If a rapidly moving neutron should hit a U-238 nucleus, the former is absorbed by the latter and thereafter can not be utilized for the splitting of uranium 235 nucleuses. We thus see that the presence of the heavier isotope 238 is somewhat of an obstacle in the development of the chain reaction. It is necessary to neutralize - if I may use that expression - uranium 238, so that the latter will not interrupt the chain reaction by absorbing the neutrons. There exist two ways for eliminating the negative influence which uranium 238 exerts on the chain reaction. The first method is simply based on the separation of both isotopes from each other and the attainment of pure uranium 235. We will discuss the second method later, in connection with the application of atomic energy in industry. The task of separating uranium 235 from the heavier U-238 appears to be a simple matter, but in reality it is very difficult. First of all, both isotopes possess the same chemical properties - they are x atoms of the same element, uranium. They can not, therefore, be separated by any chemical means. The only thing that differentiates them is the minute difference in weight. In order to separate the two isotopes, it is necessary to utilize in some way this minute difference. One of the methods for separating uranium 235, called gas-diffusion, is based on running gaseous uranium fluoride through porous walls. The lighter particles containing U-235 more easily pass through the walls, so that after running through several times we obtain a gas that is enriched with U-235. This process is tedious and lasts a long time, the more so because there is really very little of the valuable U-235 available. In natural uranium for 140 atoms of U-238 there is only 1 atom of U-235. Even many pumpings through the above-mentioned walls will not provide us with pure U-235 but with a mixture in which there will be for instance 50 percent atoms of the valuable lighter isotope. Another method is based on the application of centrifugal force. Under the influence of the rapid rotating movement of the turbine, the heavier U-238 atoms collect on the outer sides while the lighter ones collect closer to the center. We can thus gradually separate both isotopes from each other. These methods do not, however, allow forx a complete separation of both isotopes but only lead to a certain enriching of the mixture with the valuable Uranium 235. There exists, however, yet another method based on curving the path of the electricized atoms on the electric and magnetic fields. The heavier atoms experience a smaller curve than do the lighter ones. By this means, we can separate them from each other completely. The disadvantage of this method is that it can only be utilized for the operation of very small quantities of material. In practise, both methods are applied in sequence: first, the coarser isotopes are separated by gas-diffusion or in turbines. Next, this material enriched with U--235 is processed by the electrical (or magnetic) method.

Let us say for example that we have obtained pure U-235. Will the chain reaction and explosion take place for certain after this? This will depend upon how large the quantity of pure Uranium

-235 is that we have obtained. If, for instance, we possess a cube of such uranium that weighs only a few hundred grams, such a cube will be harmless and will be of no danger to anybody. It will be a simple piece of metal. Should we combine several such cubes into one cube weighing for example a half of one kilogram, still nothing extraordinary will take place. If we continue to add further x pieces to the existing block of uranium, there will at last come a critical moment when an explosion occurs destroying us and the surrounding vicinity. How can we explain this awe-inspiring property of U-235? The explanation is quite simple. While the cube is small, the chain reaction cannot develop because the majority of the newly formed neutrons will fly out beyond the limits of the cube of uranium, not hitting any nuclei on their way and thus not contributing to the disintegration of further atoms and the further production of neutrons. It should be reminded that nuclei are infinitely small and that the chances of hitting any nucleus by a neutron, before it leaves the area of the cube, are also small. However, the longer the path over which the neutron must pass in order to arrive at the surface, the larger is the chance x that it will hit some nucleus and will contribute to a further development of the chain reaction. When, therefore, we enlarge evermore the dimensions of the cube, we will arive at a stage where the pro- bability that the neutron will hit the nucleus is greater than the probability that the neutron will get out beyond the confines of the cube. At this point, the number of neutrons formed in the subsequent steps of the chain reaction will really increase until a considerable part of the uranium disintegrates. But the disintegration of a large quantity of uranium is connected with the libera- tion of tremendous quantities of energy and takes place so quickly that it is equivalent to an explo- sion of cataclysmic proportions.

In such a way, therefore, we have found a simple explanation for the secret properties of pure uranium 235. In small quantities, it is an absolutely harmless metal. It can not exist at all in larger quantities, because an explosion may oc- cur while adding small pieces to a larger one. The actual critical size remains a secret. It is con- jectured, however, that this size must be approxi- mately 1 kilogram.

The atomic bomb thus must consist at least of two separate pieces with a weight of less than one kilogram and of a mechanism which can connect the two pieces with each other at the desired time. No igniter is necessary, because single neutrons are wandering everywhere in nature. They can start a chain reaction at any time.

(to be continued)