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ATOMIC ENERGY

THE announcement from Washington on August 6, of the production of atomic bombs more powerful than 20,000 tons of T.N.T. and possessing blast power over 2,000 times that of the British 22,000 pounder, has taken the world by surprise. It appears that the Japanese town of Hiroshima on which it was first dropped is almost completely destroyed. The reactions that followed the above announcement can be briefly summarised. First, there was excitement that under the stress of war the process of releasing atomic (nuclear) energies on a large scale has reached a stage of perfection though for the time being for destructive purposes. Then there was a feeling of confidence that the Japanese War would come to an end sooner than expected. This has since been found to be justified. Finally, every human being capable of comprehension was shocked to hear about the devastating effect on civilization of this new and revolutionary weapon of destruction. This sense of horror was followed by a prayer that "these awful agencies will be made to conduce to peace among nations and that instead of wrecking measureless havoc upon the entire globe, they may become a fountain of world prosperity".

The idea that the core of the atom is a store-house of energy is not of recent origin. The study of the subject started with the discovery by Becqueral towards the end of the last century, of a phenomenon exhibited by uranium, the heaviest of all the known elements. This property which is now known as radio-activity is the spontaneous disintegration or splitting up of atoms with the emission of charged particles. Subsequent experiments revealed the existence of a number of radioactive substances, all of them derived from one of the two parent substances, namely uranium and thorium, which were continuously radiating and producing each a new element. Radium is one such transformation product emitting very penetrating radiations which have been used for treatment of cancer, etc. During these transformations, though small in number, energies of the order of a few million electron volts are released. (One electron-volt energy corresponds to about 10^{-12} of an erg.) In a gram of uranium about 24,000 atoms break up per second with the emission of alpha particles. (An alpha particle is a doubly ionised helium atom.) Yet the number of atoms in a gram is so great that it would take about 4,500 million years before half the atoms are transformed. As it was not possible to influence these spontaneous disintegrations of atoms by any physical processes, we could not accelerate the production of energy by this means.

Further investigations on this subject by Lord Rutherford and his school gave us some idea about the structure of atoms. It is now known that the atoms of all elements have a similar type of structure. The atom consists of a positively charged nucleus carrying most of its mass. The nuclear charge which is also called the atomic number, has a value 1 for hydrogen and 92 for uranium. The nucleus is surrounded by a cloud of negatively charged particles called electrons whose number and distribution as well as the chemical properties of the element as a whole are controlled by the nuclear charge. Elements having the same nuclear charge or atomic number but different masses are called isotopes. It is now a well-established fact that the majority of the elements consist of a mixture of isotopes.

In the ordinary chemical processes in which only the outer electrons take part, the energy released is of the order of a few electron-volts per atom; this is only about a millionth part of the energy released during nuclear transformations. It is easy to imagine the stupendous rise in energy that could be effected by carrying out nuclear transformations on a very large scale.

In 1919 Lord Rutherford showed that the nitrogen nucleus was transformed when the latter was bombarded by the powerful projectiles of alpha particles from radioactive sources. In the succeeding years it was established that a number of light elements could also be transformed in a similar way. As a result of a close study of these artificial transformations, the existence of a new type of particle of great importance called the neutron was discovered in 1932. These are formed when the element beryllium of mass 9 is bombarded by alpha particles from radium. As the neutron is electrically a neutral particle having a mass nearly equal to that of a hydrogen nucleus, *i.e.*, a proton, it can penetrate the electrical barrier of the nucleus with but little opposition. Fermi was the first to realise that the neutron was a most promising agent for effecting nuclear transformations especially in the heavy elements.

Soon after the discovery of artificial radioactivity by Curie and Joliot in 1933, Fermi observed that radioactivity could be induced in many elements by neutron bombardment. By bombarding uranium and thorium with neutrons, Fermi and his associates obtained a series of new radioactive bodies emitting negative electrons, and from their chemical behaviour they were led to believe that these activities belonged to elements having atomic numbers greater than 92. These new elements were called trans-uranic elements. Hahn, Meitner and Strassman extended these investigations. They definitely established in January 1939 that isotopes of barium of atomic number 56 and of lanthanam 57 were formed as a consequence of the bombardment of uranium and thorium with neutrons. Similar results were obtained by Curie and Savitch almost simultaneously. These results suggested that after neutron capture the uranium or thorium nucleus splits up into two nuclei of medium atomic weight giving rise to a new type of disintegration—*nuclear fission.* Meitner and Frisch offered an explanation of the phenomenon of fission on the basis of the Böhr nuclear model. With sufficient energy of excitation, the heavy nucleus breaks up into lighter nuclei, just as a liquid drop will split up into smaller drops if enough energy is given to it. It has been shown that after splitting, the fission products will gain a total kinetic energy of the order of 200 million electron-volts. The energy released during fission is, therefore, more than twenty times the energy released in the ordinary nuclear transformations. Numerous investigations carried out in various laboratories have established that fission can be induced in uranium, thorium and protactinium not only with neutrons but also with high-energy charged particles such as deuterons, protons and alpha particles.

At the instant of fission the products are formed in a very highly excited state and consequently direct liberation of neutrons will take place. This was experimentally confirmed by Joliot, Halban and Kowarski. They showed that several secondary neutrons are emitted during each fission of the uranium nucleus. These are of a different type, *i.e.*, they are fast or high-energy neutrons. Thus a single neutron causing a rupture of the nucleus not only liberates vast quantities of energy, but also produces additional neutrons which can in turn cause further fission, thus releasing more and more energy. A great deal of interest is attached to this discovery as it leads to the possibility of a cumulative process of exothermic disintegration or chain reaction releasing terrific amounts of energy in a very short time and ending in a catastrophic explosion. This aspect of the problem which was only of theoretical interest in the year 1941, appears to have been fully worked out, resulting in the manufacture of the atomic bomb.

The necessary condition for the progress of the chain reaction is that at every stage the average number of secondary neutrons produced per fission should always be greater than the number that would be lost by capture processes which do not result in fission. This has been achieved by using fairly large quantities of a suitable compound of uranium isotope of mass 235 as the main constituent of the bomb and thermal neutrons as exciter of fission. Uranium has two isotopes, one of atomic weight 235, the other of 238. Nier, Booth, Dunning and Grosse who investigated nuclear fission in separated isotopes of uranium, showed that the yield of slow-neutron-induced fission in the lighter isotope is many times greater than in the heavier isotope. The lighter isotope is only a small fraction of the natural uranium which itself is a rare element. The practical problem is, therefore, to concentrate large quantities of the uranium of mass 235. This has been accomplished at a cost of a few hundred million sterling. Of the well-known methods of separation of isotopes, either the thermal diffusion method or the mass spectrographic method might have been developed successfully for the production of uranium 235 on a large scale.

As has already been remarked, the secondary neutrons emitted during the process of fission are of very high energy and in order to produce the chain reaction, it is necessary to introduce some hydrogen-containing substance to slow the secondary ones. Heavy water appears to have been used for this purpose. This refinement in technique has the additional advantage that during the process of slowing the high energy neutrons by collision with the heavy hydrogen or deuterium nuclei, more neutrons will be emitted as a result of the dissociation of the latter.

When once a large quantity of the atomic dynamite is available, it is comparatively easy to devise a trigger mechanism by which a beam of neutrons could be released suddenly at the right time for exploding the dynamite. It is of the utmost importance to see that the stray neutrons which are to be found everywhere due to cosmic radiation do not prematurely blow up the bomb. The use of a large quantity of silver in the manufacture of the atomic bombs has been reported. It is not unlikely that the silver may have been formed into containers for the explosive material, to absorb any stray neutrons of cosmic-ray origin.

It is estimated that one cubic metre of uranium oxide is capable of developing 10^{12}

kilowatt-hours of power in less than 0·01 sec. The sudden release of such a tremendous energy gives rise to a blinding flash many times brighter than the mid-day sun, which is followed by a tremendous and sustained roar and a heavy pressure wave. This causes destruction to men and material on a scale hitherto unknown. Because of this fact, the discovery of the atomic bomb has made warfare terrific beyond imagination. It is therefore imperative that in future the production of this new type of weapon should be effectively controlled in the interests of the whole world and not of one nation or another. It is to be hoped that in the mean time no efforts will be spared by the nations who are in the know of the secrets of the atomic bombs towards finding a suitable antidote for the same.

If the tremendous energy released from atomic explosions is made available to drive machinery, etc., it will bring about an industrial revolution of a far-reaching character. It is estimated that a pound of uranium can generate the same amount of power as a few million pounds of coal. But there are obvious difficulties connected with the control of the evolution of atomic energy. It is easier to make a destructive bomb on the atomic principle than it is to harness atomic power for peace-time purposes, and a great deal more research work is needed before atomic power can be put to industrial use. It is necessary to emphasize that the prospects of producing cheap atomic power are none too bright, however, if the chain reaction can be propagated only by slow neutrons acting on the less abundant isotope of uranium. It is to be hoped that practical ways may be found for utilising the transmutations of the commoner elements for the production of power.

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IMPERIAL CHEMICAL INDUSTRIES (INDIA) RESEARCH FELLOWSHIPS

At the Ordinary General Meeting of the National Institute of Sciences of India held at Calcutta on the 23rd July 1945, Mr. D. N. Wadia, President, announced that he had received a letter from Lord McGowan, Chairman of the Imperial Chemical Industries, forwarding a document offering to the National Institute a sum of Rs. 3,36,000 for creating Research Fellowships in Chemistry, Physics and Biology at the Indian Universities or institutions approved by the Council of the National Institute, for over a period of five to seven years. The reasons and hopes which had prompted the Imperial Chemical Industries to offer a number of Research Fellowships to the Institute were explained by Lord McGowan in the following words:—

"The National Institute of Sciences is, we believe, destined to play in India a part similar to that which the Royal Society of London has performed for nearly three hundred years in leading the scientific progress of this country.

"The Royal Society until recent years was hampered by lack of funds and provision for the maintenance of scientific workers. This difficulty was eventually overcome by the generosity of various benefactors, including Industrialists such as Mond and Messel.

"We thought, therefore, that there could be no better way of encouraging the advance of science in India and with it the general prosperity of the country than by the offer of these Fellowships which under the wise administration of your Council will, we hope, lead to an augmentation of the distinguished successes in science already attained by so many of your fellow countrymen."

The following are the terms under which the fellowships are to be created:—

1. Each fellowship to be worth Rs. 400 per month and to be tenable in the first instance for two years, with a possibility of extension up to a total of three years. (It is assumed that half the fellowships will be extended for a third year.)

2. In addition there will be a grant for research expenses to be made to the fellowship holders according to their needs of special apparatus and materials. For this purpose the National Institute will have at their disposal an average of Rs. 600 per annum for each fellowship.

3. There will be a grant of Rs. 13,200 per year to the National Institute for five years to enable them to pay for administration and the travelling expenses of such fellows of the Institute as may be selected to visit the fellowship holders at their Universities or Institutions.

The National Institute of Sciences is asked to administer the funds for the fellowships on the following principles:—

1. Appointment to and control of the fellowships to be made by the Council of the National Institute, acting on the advice of a special research fellowships committee.

2. This Special Research Fellowship Committee will represent various scientific fields and be drawn from various parts of India, so as to include any community, the over-riding consideration for membership being scientific fitness therefor.

3. The fellowships will be open to persons, irrespective of sex, race or religion, resident or domiciled in India (British India or the States) and under 35 years of age.

4. The fellowships will be tenable at any University or Institution in India, approved by the Council of the National Institute.

5. Fellows will be permitted to do a little amount of approved teaching or demonstrating. This should not be more than six hours per week and it should be a condition that they are paid for this work by the Institution or University at its normal rates.

6. The aim of the fellowships is to strengthen research in Indian Universities and Institutions, and it is hoped that the National Institute of Sciences will spread the research fellowships over them in accordance with this aim, but with the over-riding consideration of the scientific suitability of the particular University or Institution.