T H E   C Y C L O T R O N

Yes, a ship-load of steel and copper is a lot to put in any machine. Nearly 5000 tons for a cyclotron to smash atoms. 5000 tons to smash something you can't see. It's fantastic (you say), it's madness, stark madness. Sounds very much like that, I admit. So let's go straight for the business end of this talk. Let's see what atoms are and what it means to smash them.

Out of the window I see a neon sign over the entrance of a down-town theatre. It gives out a rather attractive red light. But when the sign is switched off the gas is transparent and colorless.

Now why is neon a gas? Why does it have these characteristics? The fundamental point in the answer is unbelievably simple. Of course it has to do with atomic structure.

There is a sort of governing body sitting at the center of each atom of neon. Ten positively charged particles rule the show. These ten protons (as they are called) packed into the core or nucleus of each atom give neon its whole character. Of course, there is an outer structure - a relatively delicate outer structure of electrons built round the nucleus - but even this is ruled by the ten protons. That's because ten positive charges of electricity can hold just ten negative electrons. So while this rather loosely bound outer structure is directly concerned with all chemical and physical properties of neon gas - still this very structure <u>exists</u> because it is held together by the ten protons. These ten protons do rule the show.

But are there not other things in the nucleus, along with the protons? Yes, <u>neutrons</u> are there. Each neutron has about the weight of a proton, but no electric charge. So neutrons appear to have no vote. Apparently you may throw as many or as few as you like into the nucleus and you will still have neon. That's correct.

Next we come to the central point in our talk. For scientists have found only certain numbers of neutrons in combination with the ten protons. There may be 10 or 11 or 12. No other number of neutrons will form a stable combination with the protons. By means of the cyclotron it has been possible to build neon atoms with 13 neutrons. They were perfectly good neon atoms - while they lasted. But they blew up, giving off radiations like those from radium, and then they became atoms of the metal sodium. Yes, neon gas turned into one of the components of table salt. This process is called artificial radioactivity, since it started from an artificial form. But generally speaking it is similar to the natural radioactivity of the metal radium which gives off penetrating rays and turns into the gas radon. All activities, artificial or natural, arise from combinations of protons and neutrons which will not hold together. Radium is one such form that still is found in Nature, but if we want active forms of other chemical elements they must be built up. Built up or torn down - it doesn't matter - so long as some new combination is obtained.

By means of the cyclotron such new forms are made up. Then they break down of their own accord. That is called atom smashing. Hundreds of new forms have been made. Every last chemical element can be made radioactive. Each chemical element may be changed into another. Hydrogen into helium, phosphorous into sulphur, and so on.

But <u>how</u> are these new forms made? By shooting particles into the nucleus with enough force to change the structure. And the best practical source of such fast particles is the cyclotron.

Cyclotrons commonly weigh from 50 to 200 tons. At the beginning of the talk I referred to the new one planned by Professor Lawrence in California. It will weigh nearly 5000 tons. No, not just bigger and better. But even a 200 ton cyclotron will do a good job. An electromagnet is the chief item. Next there is a huge flat bronze pill box affair known as the vacuum chamber. It's five feet in diameter and fits in between the poles of the magnet. This box contains the more vital parts of the cyclotron - and just a trace of hydrogen gas. Finally there is a wireless transmitter such as might be used in a high power broadcasting station.

Let's now go back and look inside the vacuum chamber. Suspended within this box is a smaller pill box of thin sheet copper. The copper box is cut in two, and the halves are separated a few inches. These hollow shells don't touch the walls of the outer casing, but they help form part of the wireless oscillator. That means only that a current of electricity surges up into one of them, then runs back and surges into the other. The more power that is supplied by the wireless outfit, the greater the alternating voltage developed between the two copper shells. 100,000 volts is an average value. In spite of this low voltage, the cyclotron operates as a 10 to 20 million volt machine. This remarkable operation is rather well known, but maybe worth repeating.

So let's start the thing going. First we must use that trace of hydrogen gas. Get the boy to knock off the electron. Now we have the positive nucleus. It will be the bullet for atom smashing. Of course we'll need lots of them, and will start near the center of the vacuum chamber. When the wireless oscillator takes a surge in the right direction, 100,000 volts will pull the positive particles into one of the copper shells. They will be whirled round by the magnetic force. Everything is set so that just as they start to cross the gap between the copper shells a second time the voltage is reversed. So the particles get another 100,000 volts. The particles go faster and faster, in bigger and bigger circles, but always reach the gap just in time to get 100,000 volts. By the time they reach the outer limit of the pill box casing, they have a speed which might have been produced in one stroke by <u>20 million volts</u>. A deflector plate is used to pull the stream of fast particles off the race track and direct it toward a water cooled target. Any target whatever will be made radioactive by this beam from the cyclotron. Stick your hat in the beam or your fountain pen or diamond rings. They will be made radioactive.

Actually, what is happening? The first point is the need of a positive charge on the bullet in order to speed it up in the cyclotron. Unfortunately, the second point is that this bullet will then be repelled by the positive charge on any nucleus, and will tend to swerve to one side and produce no results. Therefore it is necessary to give so much speed to the bullet that it will overcome this repulsion and drive right into the nucleus. The outcome is usually some one or more of the new unstable forms.

There is another phase of the work with cyclotrons which is of some interest to the medical profession. If what is known as heavy hydrogen is used in the cyclotron and the very light metal beryllium is employed as the target, then there immerges from the target a remarkably strong stream of neutrons. Since these carry no electrical charge they are rarely deflected in their path through matter and hence they penetrate lead and such material as readily as X-rays. So they may be used as X-rays are used to radiate biological bodies.

Now let's take a minute to sum up what the cyclotron brings to science: First the means for carrying out experiments on the center of the atom. This looks like one of the last strongholds of nature and it is good to know how it is put together. Next it's a universal philosophers' stone which changes copper into zinc, tin into antimony - hundreds of such changes. Of course as yet on a small scale. Then there is the long list of new radioactive forms which may be carried away from the cyclotron and still retain their radioactivity. Some last for a few seconds and some last for years. By their radiations they may be followed by chemists or biologists who are often glad to know exactly the part played by certain atoms or molecules in their studies. Used in this way the new radioactive forms are one of the most powerful tools ever introduced into science. Finally, there are just a few atoms which split wide open. About two years ago it was shown that if a neutron is plugged into a uranium nucleus (which already has 92 protons and 143 neutrons) then this nucleus splits into two parts. Each part carries away about 50 million volts. In the debris following the explosion there are a few stray neutrons. But the two atoms that are first formed from the one atom of uranium are not themselves stable. They keep changing over to others until perhaps ten different kinds of atoms are obtained from one atom of uranium. This is not a matter of putting a lot of energy into uranium. It's just a matter of pulling the trigger.

For eight years we hoped to build a cyclotron at McGill. A fine group of McGill men went to California to learn this great game. Bob Thornton and Arthur Snell, Don Hurst and now Lawrence Walker. They have made fine records. Meantime a small group at Montreal were encouraged by the McGill authorities to plan for an excellent cyclotron here in Canada. Ferdie Terroux and Ross McRae and myself. We had a very happy time with those plans, and we learned a lot. Then the war came and quite suddenly Ross died. He was one of my best friends. He had the greatest love for truth, and he was able. Now our plans have been temporarily set aside to meet the vital demands of today.

McGill University,
October 4, 1940.

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