Ernest's Nuclear Atom

Ernest Rutherford was born in New Zealand into a poor farming family in 1871. When the young "Ern," as his family called him, received his first science book at the age of ten, he was hooked; nevertheless, he still had to keep working at the farm chores. He was very studious and managed to obtain university scholarships. Throughout his university days in New Zealand, he studied and invented high-frequency electrical circuits and worked with radio waves. After he graduated with his Master's degree, he looked for a job as a school teacher. Evidently, he must not have been very good at it because, even after his third try, he could not get a permanent job. When he fell in love with the beautiful Mary Newton, he decided that without a good job, they could not afford to get married. Failing to get a job, he went back to his parents' farm to help with the work.

At the same time, Ernest applied for a science research scholarship, with which he would be able to take his doctorate anywhere in the world. He was on the field digging potatoes when his mother came running with the news, "Ern, you won't believe this—you've got the scholarship anyway…". The twenty-four-year-old Ern dropped his potato fork and said, "That's the last potato I will ever dig!" What a major stroke of luck—although he had placed second in the scholarship competition, the prize had been awarded to him when the winner decided not to take it.

The second major turning point in his life occurred when he chose Professor J. J. Thompson (known as JJ by his students) at Cambridge University's Cavendish Laboratory as his doctoral supervisor. Cambridge had just instituted the new "Doctor of Philosophy" degree, and Rutherford was among the first few to earn this degree. By 1898, at the age of 27, with JJ's help, Rutherford obtained his first job as professor at McGill University in Montreal, Canada. Finally, he was also able to marry his sweetheart, Mary, who had waited for him all this time.

At McGill, Rutherford made his first great discovery–that the atom is composed of parts and that its character can change. One of the atomic parts he discovered and identified was the alpha particle, which is, in effect, just a helium atom with its electrons stripped off. His discoveries in this field were considered so important, that he received the Nobel Prize in Chemistry in 1908 "*for his investigations into the disintegration of the elements, and the chemistry of radioactive substances.*" By then, he had been induced to move to Manchester, England to accept his second job as head professor of physics there.

One spring day, in March of 1909, Ernest Rutherford was sitting at his desk, deep in thought. He realized that he had achieved a level of success that other scientists could only dream of—a Nobel Prize at age 37! Why, then, did he still have these nagging thoughts of dissatisfaction? "For all I have discovered, I still have no clue of what the atom really looks like," he mused. "I certainly don't accept JJ's theory that the atom is some sort of blob of positive and negative charge distributed, more or less, uniformly." His mind went back to his experiment of shooting a beam of alpha particles at a sheet of mica and taking a picture of the beam on the other side with a photographic plate. What should have been a sharp, bright point was not so; it was fuzzy. Why? Surely, the heart of the atom could not be a positive charge concentrated in a small area, could it? Surely, the alpha particles were not bouncing like marbles from the center of the atom, were they?

Rutherford's thoughts were interrupted by a faint knock at the door. "Come in!" his voice boomed. His research associate, Hans Geiger, entered with a young man in tow whom Rutherford had not met before.

"Professor, this is Ernest Marsden, one of our students who is in need of an undergraduate research project. I have been training him in radioactive methods. Do you think that he might begin a small research project with us?" Hans spoke with a thick German accent, having recently arrived from Germany to take up the John Harling research fellowship at Manchester in order to work with Rutherford.

"I think that is a good idea, provided that Ernest is willing to work at the arduous task of observing scintillations."

"Scin-Scintillations, sir? What are they?" stammered Ernest.

"They are the tiny flashes of light when alpha particles strike a fluorescent screen. Of course, you can't see them unless you use a microscope, and your eyes can't detect them unless you first sit in total darkness for at least a half hour with your eyes open. Then, you must be prepared to stare into the microscope and hold your eyes open without blinking for at least two minutes at a time and count all the flashes you see. It's not easy."

"Sir, I am willing," replied the young Marsden.

Rutherford had a flash of inspiration. "Then, why don't we have Marsden, here, look for alphas that are scattered through a large angle? It has never been done before."

"Agreed," said Geiger.

"Then we will go ahead," replied Rutherford, and Marsden nodded. Rutherford, though, had a sheepish look on his face. What he had not said is that he had no confidence that Marsden would succeed. What if he failed? How would that affect the student's future studies?

Three days later, Rutherford, as usual sitting at his desk and writing, was interrupted by a loud knock at the door. Rutherford jumped, his concentration having been broken. "Come in!" he said with his usual booming voice.

The door swung open and Geiger strode in, obviously in an excited state. "Professor, Professor, we have made the most incredible discovery—some of the alpha particles are coming backward towards the source!"

For a moment, Rutherford was at a loss for words. Then, he replied, "Hans, explain yourself!"

Geiger continued, "We have used a radium source to project alpha particles at a gold foil mounted on a thin, glass plate and find that about one in twenty-thousand of the alpha particles have their directions changed to such an extent that they emerge again at the side of incidence."

Rutherford was stunned. "That is incredible. If the atom is, indeed, like JJ says it is, that would be about the equivalent of shooting a 15-inch artillery shell against a target of tissue paper and having it bounce back towards the gunner!"

Geiger laughed, "I hadn't thought of it quite that way…."

Rutherford's eyes glazed over as he spoke to himself, "This means that we must, indeed, revise our picture of the atom. I wonder…."

Geiger interrupted, "Sir, should we complete the experiment and write it up for publication?"

"Yes, indeed. Let us do it with all haste."

The next two years passed like a whirlwind, with experiment after experiment revealing more detail about the scattering of alpha particles when passing through matter. It was the Sunday before Christmas in 1911 and the Rutherfords had decided to host a Christmas dinner for their friends and colleagues. After supper, Mrs. Rutherford served the traditional Christmas plum pudding. Instead of digging right in, Rutherford just stared at his pudding.

"Is something the matter, dear? Why don't you eat your pudding?" Mrs. Rutherford asked.

Rutherford uncharacteristically ignored her question and, instead, began to speak excitedly, "Now, I see it—why JJ's model cannot be right—and what the atom must be like. It cannot be like this pudding with the negative charges like the plums and the positive charge like the dough. The positive charge must be concentrated in a small region in the center, and the negative charge must be located, perhaps, like a cloud around the center."

The dinner guests were suitably impressed by Rutherford's insight, and an animated conversation took place. The next morning at the laboratory, Rutherford met with Geiger, as usual.

Triumphantly, Rutherford announced, "Hans, I know what the atom looks like and how we must explain the large scattering of alpha particles. Most of its mass is concentrated near the center as the positive charge, and the negative charge in the form of electrons is much smaller and further away from the center."

Geiger appeared somewhat concerned. "Professor, that is certainly a revolutionary idea and will not be viewed too kindly by JJ."

Confidence rang in Rutherford's voice. "If JJ had not put forward a theory of his own, he would

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have to admit that I am right, as the evidence is very strongly against him."

Rutherford published the details of his new model of the atom, but not too many people believed him at the start. It remained up to Niels Bohr to join Rutherford and devise his Bohr atomic model, which was a refinement of Rutherford's idea and the first model that explained the atom in a way that was consistent with all the known observations.

So, that is the story of how the idea of the nuclear atom was born, but it was not until two years later that Rutherford first used the word "nucleus" to describe the center of the atom.

References

Geiger, H., & Marsden, E. (1909). On a diffuse reflection of the alpha particles. *Proceedings of the Royal Society of London A, 82*, 495–500.

Moon, P. B. (1974). *Ernest Rutherford and the Atom*. London: Priory Press Limited.

Niaz, M. (1998). From cathode rays to alpha particles to quantum of action: A rational reconstruction of structure of the atom and its implications for chemistry textbooks. *Science Education, 82*, 527–552.

Reeves, R. (2008). *A Force of Nature: The frontier Genius of Ernest Rutherford*. New York, N.Y.: W. W. Norton & Company, Inc.

Rutherford, E. (1911). The scattering of alpha and beta particles by matter and the structure of the atom. *Philosophical Magazine, 21*, 669–688.

Wilson, D. (1983). *Rutherford: Simple genius*. Cambridge, MA: MIT Press.

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