# The Rutherford Model in Trouble

It cannot be denied that the Rutherford model of the atom gives an excellent explanation of the interaction between atoms and alpha particles, and also can be expressed in terms of mathematical equations that can go into the nitty-gritties of all the observations. But there were also some serious problems with this model.

If the positive charge in an atom is present in its nucleus and the unmoving, negatively charged electrons are scattered around this, then because of attraction between the opposite charges, the electrons should be attracted to the nucleus and fall into it. Atoms are fairly stable entities. So, the first objection to Rutherford's model was why do the atoms not collapse into themselves, in no time at all?

This issue was solved to some extent by proposing that the electrons were orbiting around the nucleus. When any particle is revolving around some other particle, then it experiences a centrifugal force, and it was said that the centrifugal force experienced by the electron orbiting around the nucleus balanced the electrical attraction between them and hence the electron was able to remain in its orbit. So, the Rutherford model of the atom became one in which there was a small positively charged nucleus at the centre with the electrons orbiting it at some distance. Don’t you think this looks a bit like the solar system now?

But even this model was not problem-free. This time, the problems arose from the study of light.

Now, we are talking about the events of 1911. It was known by then that if the electron was going around the nucleus, then it was experiencing acceleration. And an accelerating electric charge was known to emit radiation and hence it would continuously lose energy. So, atoms were emitting this radiation in the form of electromagnetic radiation. And with this loss of energy, the orbit of revolution of the electrons should continuously reduce and in very little time they should fall into the nucleus. So, this model with the orbiting electrons also proved to be unstable.

There was a third objection to this model too. And it was in actually trying to solve this third puzzle that Niels Bohr arrived at the next model of the structure of the atom. So, let us try to understand this third problem and go into it in detail.

By then, there were many studies of the spectrum of light. It had been found that every substance had a definite and unique spectrum. Bunsen had carried out some excellent studies with his experiments on the spectrum of various substances. And on the basis of the analysis of their spectrum, he had even managed to identify new elements like rubidium and cesium. The analysis of the Sun's spectrum had led to the discovery of the presence of helium there. The theory that had been developed to account for all this was that the spectrum of each element was due to the radiations emitted by the electrons in the atoms of these elements.

If Rutherford's model were correct, then what were its implications for this phenomenon?

In Rutherford's model, the electron orbits around the nucleus and slowly but continuously, the orbits getting smaller. That is, their energy should be emitted in the form of electromagnetic radiations. If the orbital path was becoming smaller, then light of all wavelengths should be emitted and the wavelength of the light being emitted should continuously become smaller.

But the facts about the spectrum of elements were not like this. If we were to look at the spectrum of any element, then it did not contain light of all wavelengths. The spectrum of each element was not continuous, but discrete. This means that light of some wavelengths are missing from the spectrum of any element, while more of the light of some other wavelengths are present in it.

Like when we take any metal or its compound and heat it in the flame of a Bunsen burner, then light of a particular colour can be observed. The ubiquitous flame test is based on this finding. For example, if we take a sodium salt and heat it in a flame, and pass the light being emitted in this process through a prism to split it, then one gets a specific spectrum.

This type of spectrum is called an atomic spectrum. J. J. Baumer (1825-1898) was the first to study atomic spectra in detail. He had been looking at the spectrum produced by hydrogen kept under low pressure. And he found that the wavelengths present in the atomic spectrum of hydrogen could be expressed in the form of an equation. Alongside, Rydeberg had also found that the wave-numbers (that is the number of waves in a unit length) of the emitted radiation could be written as an equation:

$$\sigma = 1/\lambda = R\{(1/n_i^2) - (1/n_j^2)\}\mathrm{cm}^{-1}$$

In this equation, $\sigma$ stands for the wave number and $\lambda$ the wavelength while $n_i$ and $n_j$ are any two whole numbers, and R is a constant that is fixed for any one gas.

Now, isn't this interesting? The atomic spectrum is a complicated business. When a gas sealed in a tube under very low pressure has a high voltage applied across it, then it emits light. When this light is passed through a prism, then it is seen to be split into lines of different wavelengths. The interesting thing is that the wavelengths of these lines can be expressed as an equation which contains two whole numbers in it.

Whenever such simple equations that can express observations with such accuracy are arrived at, then this thought arises that this equation must be enunciating some aspect of reality, and is not merely a figment of one's imagination.

At this time, the field of physics was experiencing some revolutionary changes. Solid substances on heating also emitted light, and the wavelengths seen in these spectra raised some difficulties with respect to their intensities. The problem was that the intensities actually observed were not in accord with those predicted by the electromagnetic theory. In trying to resolve this issue, a physicist named Max Planck presented a hypothesis which threw the other physicists into confusion and they refused to even listen to him. But this hypothesis presented by Planck was soon to cause fundamental changes in our picture of reality. This was the Quantum Theory. The basic contention of the quantum theory was that energy was also found in the form of discrete units like matter. This meant that the energy emitted by an atom could only be of certain values.

$$\varepsilon = nh\nu$$

Here, $\varepsilon$ stands for energy, n is any whole number, h is a constant and $\nu$is the frequency of the radiation.

Another matter had come up because of the electromagnetic effect at that time. Some substances emitted electrons when they were irradiated with light (the photoelectric effect). The interesting thing was that electrons would only be emitted if the frequency of the light was of a certain energy. Whatever might be the intensity of light of a lower frequency, electrons would not be emitted. Einstein had explained this phenomenon using the quantum theory.

So, slowly it came to be accepted that the quantum theory must be expressing the reality of the atomic world.

The difficulties faced by Rutherford's model of the atom were only resolved when the quantum theory was applied to this model. And this work was done by Niels Bohr.