THE OVERCAST SKY

Asif Akhtar

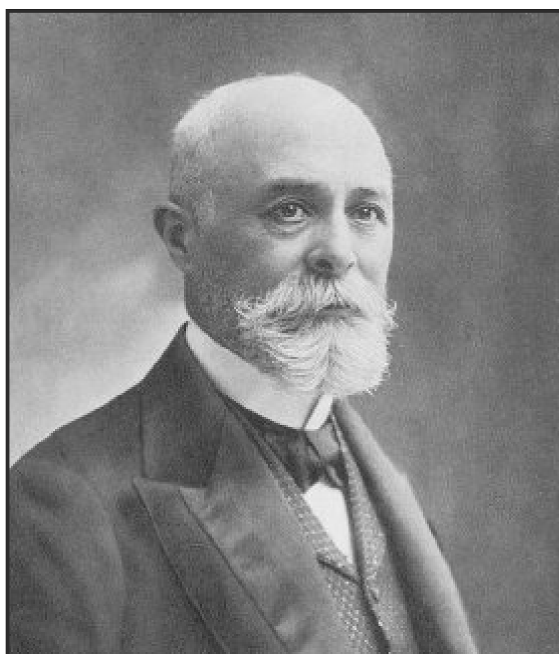
How did bad weather and a chance observation of what was most likely a failed experiment, lead to the Nobel-prize winning discovery of radioactivity? In this article, the author narrates the story of Henri Becquerel's experiments with uranium salts, describing a series of scientific investigations that arose to understand an unexpected and unusual observation, originally made by this physicist.

It was the first of March 1896, and a lazy winter day in Paris. The sun hadn't come out of the clouds once in the last four days.

The physicist Henri Becquerel, working in his laboratory, knew that on such a cloudy day, he would not be able to get any results in his on-going study. For the last few months, he had been studying the properties of phosphorescent compounds using photographic plates that were exposed to sunlight. On a sunless day, like this one, his photographic plates would remain un-exposed.

This was around the time when X-rays, discovered by Wilhelm Conrad Rontgen, were a popular subject of research in the global scientific community. The first X-rays to be detected had been accompanied by a form of phosphorescence in vaccum tubes. Henri was interested in investigating whether X-rays were in any way connected to naturally occurring phosphorescence. He hypothesised that to emit a penetrating radiation, like X-rays, a body had to luminesce.

To prove this, Henri had planned a series of experiments where he would first expose a



A portrait of Antoine Henri Becquerel.
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Wilhelm Conrad Rontgen

phosphorescent compound to sunlight by leaving it on a window-sill in his laboratory, and then, place this compound along with a metal object over an unexposed photographic plate, covering the entire apparatus with an opaque paper. The apparatus would be left in a dark bureau drawer in his laboratory overnight.

If the compound being tested was indeed luminescent, exposure to sunlight would make it glow. Exposed to this glow, an image of the metal object would be developed on the photographic plates. This glow, according to Becquerel, would suggest that the phosphorescent compound was emitting X-rays.

Henri chose to conduct his first few experiments using a supply of uranium salts that he had inherited from his father, Edmond Becquerel, also a physicist like Henri, and a leading expert of his times on the phosphorescence of solids. Although Uranium had been discovered in 1789 by the German chemist, Martin Klaproth, it was mainly used in making coloured glazes and glass, and had not received significant attention in the scientific community. In 1869, when Dmitrii Mendeleev, a chemist, placed it as the heaviest element in his version of the periodic table, where he arranged elements in order of increasing atomic weights, there was renewed interest in this element. Edmund Becquerel had studied sulphides and other compounds of uranium extensively, due to their exceptionally bright phosphorescence.

On the day our story begins, Henri Becquerel decided to develop all the photographic plates with uranium crystals that he had prepared in the previous week. Due to the wintry overcast skies in Paris, none of these had received much sunlight, and Henri did not expect to see much on his plates.

Why he chose to still develop these plates has been a subject of a lot of speculation ever since. Some of the most common reasons suggested include Henri's over-riding curiousity; or, his natural sense of thrift – he would be reluctant to simply throw away the photographic plates that he had used so carefully in setting up his experiment. Another reason that is often suggested is that Henri was scheduled to attend an important meeting in the next week, and hoped that even results from his failed experiments would be better than having nothing

Photographic plate made by Henri Becquerel showing effects of exposure to radioactivity.
Contributor: Ranveig. Accessed on: Wikimedia Commons. URL: https://en.wikipedia.org/wiki/File:Becquerel_plate.jpg

to show. The real reason for Henri's actions will probably always remain a mystery.

What is known, however, is that while he developed his plates, Henri expected to see some very light images on them, seen sometimes with phosphorescent substances exposed to very little light.

To his complete surprise, however, not only were his plates exposed, he could see some very bright images on them. This was completely unexpected. There had been no source of light in the dark drawer. Without being exposed to enough light how had the clear dark images appeared on his photographic plates?

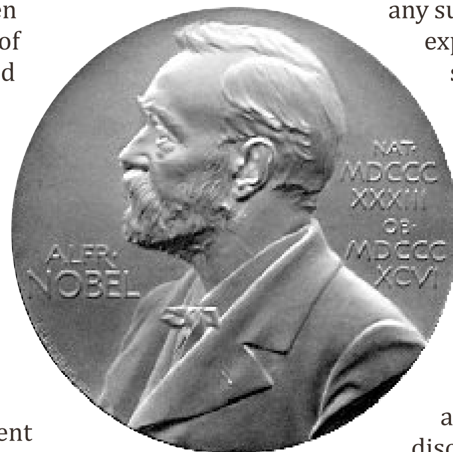
The salt which had resulted in these images on his photographic plates was potassium uranyl sulphate K2 U O2 (So4). Henri repeated his experiment with these crystals, more than once, and found the same results each time. His photographic plates showed clear dark images even when the crystals were exposed to little light.

Henri wasted no time in sending a report of his findings to the Academy of Sciences in Paris. In this report, Henri concluded that the images he was seeing were formed because potassium uranyl sulphate crystals could be stimulated by diffused sunlight, as well as reflected and refracted sunlight. He also suggested that when stimulated in this way, the uranium crystals were capable of producing radiations, which in all probability, were X-rays.

This discovery was received with great interest by the scientific community, and was widely repeated across the world – always resulting in similar images being produced by uranium salts, exposed to poor light, on photographic plates. However, it also seemed clear that though some of the energy produced by the stimulated uranium crystals were in form of X-ray-like pulses of light, these X-rays did not seem sufficient to account for the intensity of images on photographic plates, or the ability of these crystals to be able to ionise gases, or sometimes even burn physicists attempting to replicating Henri's experiment. Was this a reflection of how strongly the uranium crystals had been stimulated?

In his next set of experiments, Henri tried to determine if any light at all was needed to stimulate the uranium crystals. He did this by using the same method as before, except that the crystals used in this set were not exposed to sunlight, and the experiment was conducted in a dark room. The crystals were placed on photographic plates in an opaque cardboard box. In some of these trials, crystals were also separated from the emulsion using aluminium and glass sheets. In each case, the same results were obtained, showing that uranium crystals did not need to be exposed to light immediately before they were used to develop photographic plates, and that the images that were being seen on photographic plates were not simply the result of a chemical reaction between the crystals and the plate. This led Henri to conclude that uranium crystals did not need to be stimulated immediately before an experiment. And that they were able to produce invisible radiations that could persist for longer periods than luminous rays emitted by these compounds. However, he continued to incorrectly assume that this property was related to the phosphorescence of the uranium crystals.

He was therefore at a loss to explain why such equally intense images were found to be produced by non-phosphorescent salts like uranous sulphate. Was it possible that the ability to produce intense invisible radiations had little to do with phosphorescence, and everything to do with the nature of the potassium uranyl sulphate crystals Henri had been using in his experiments? To explore this possibility, Henri decided to investigate crystals of uranium nitrate in his next set of experiments. Uranium nitrate is known to lose luminescence when dissolved or melted in the water of its crystallisation. So Henri heated uranium nitrate crystal in darkness, protecting it using a glass tube from even the light of the alcohol flame. This compound was then allowed to recrystallize in the darkness. Heating had destroyed phosphorescence of this salt.



If Henri had been correct in assuming that only phosphorescent compounds could produce invisible radiations, these newly crystallised uranium nitrate salts should have been incapable of producing the images seen on photographic plates with uranium sulphate. However, when this experiment was conducted, the clarity of the images produced remained unaffected.

His experiments led Henri to conclude that these invisible radiations that helped develop photographic plates were not a general property of all phosphorescent compounds, but instead specific to salts of uranium. That they were produced by uranium atoms was finally proved in May 1896, when Henri showed that on using pure uranium metal, the radiations produced were 3-4 times as intense as those produced with uranyl sulphate.

This phenomenon was named radioactivity by Marie Curie. Along with her husband Pierre Curie, Marie continued her intense research on the properties of these invisible rays. Henri, Marie and Pierre were jointly awarded Nobel Prize in 1903 in Physics.

The initial observation that led Henri to this path of discovery is now celebrated as an example of serendipity, or an accidental discovery. But, like any other such accidental discovery, Henri's ability to recognise that the dark images he was seeing on his plates were only possible if the plates had been exposed continuously to an intense source of light, and in the absence of any such known source of light in his experiment, this result was unusual; shows that this discovery was also dependent on Henri's scientific aptitude. Not just that – subsequent to his initial observation, Henri's numerous experiments, often along many false trails, finally resulting in a better and more accurate understanding of the phenomenon of radioactivity, is a testament to the hard work and perseverance involved in this discovery.

In the last 119 years, these invisible radiations have been recognised as both a boon and a curse. On the one hand, this phenomenon has resulted in the production of a large source of energy in the form of electricity; and has been used to save the lives of hundreds of thousands of cancer patients. While, on the other hand, it has helped produce nuclear weapons capable enough to annihilate mankind from planet Earth.

References

1. Discovery of radio-activity. Kamble, V. B. (2015, March 22). Retrieved from www.vigyanprasar.gov.in http://www.vigyanprasar.gov.in/dream/apr2001/radioactivity.htm

2. Benchmarks: Henri Becquerel discovers radioactivity on February 26, 1896. Carolyn Gramling. Earth Magazine, February 28, 2011. URL: http://www.earthmagazine.org/article/benchmarks-henri-becquerel-discovers-radioactivity-february-26-1896.

3. "Henri Becquerel - Biographical". Nobelprize.org. Nobel Media AB 2014. Web. 27 Jun 2015. http://www.nobelprize.org/nobel_prizes/physics/laureates/1903/becquerel-bio.html

4. Henri Becquerel. (2015, June 27). In Wikipedia, The Free Encyclopedia. Retrieved 14:55, June 27, 2015, from https://en.wikipedia.org/w/index.php?title=Henri_Becquerel&oldid=668908867

Asif Akhtar *is a resource person and member of the Science Team at the Azim Premji Foundation District Institute, Almora. He has been teaching biology and chemistry at high school and Inter college level for two decades. Asif enjoys reading science fiction, and drawing cartoons on science and social issues. He has been a regular contributor in Vigyan Pragati, a science magazine published by the Council of Scientific and Industrial Research, New Delhi, in 1980s. He is also the founding president of Bio-thinkers, a science popularization organization based at Patna.*