Marie Curie and the 1903 Nobel Prize in Physics

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Marie and Pierre Curie shared the 1903 Nobel Prize for their researches on radiation. Marie Curie also won the 1911 Nobel Prize in Chemistry for the discovery of the elements radium and polonium. In this paper I will write about Marie Curie's life and her extensive study of radium and radioactivity. I will also write about the impact of Marie's research on today's life and the advances it has lead to, such as in physics theory, cancer treatment, dating techniques, nuclear energy and the atomic bomb.

Marie Curie's birth name was Maria Sklodowska, nicknamed Manya. She was born the youngest of five in Warsaw, Poland on November 7, 1867. Since 1815, Poland was not actually an independent country but was divided among Russia, Prussia, and Austria. Despite the foreign control, Mr. and Mrs. Sklodowska raised their children with great patriotism towards Poland. The czar of Russia was in control of Warsaw, and he put much effort into abolishing Polish patriotism. The private Polish schools were under careful watch by the Russian police. The private schools were not allowed to offer diplomas, only the Russian government controlled schools. Finances decreased for the Sklodowska family. The parents were both educators, but Mr. Sklodowska was continuously demoted to lower teaching jobs.

The day finally came when Maria was able to leave for a European university. With the help of Bronya and their father, Maria had just enough for tuition and the basic necessities of living. In 1891 at the age of 24, Maria left for Paris, France and enrolled in the University of Sorbonne. Overcoming her initial lack of math, science and French, Maria finished her master's degree in physics in 1893 and math in 1894. In 1895, Marie married Pierre Curie. Together they would lead a life filled with study, experimentation, and discovery.

Two recent discoveries influenced Marie's decision for a doctoral research topic: Wilhelm Roentgen's 1895 discovery of X-rays and Henri Becquerel's 1896 discovery of rays emitted from uranium compounds in light or dark areas. Roentgen used a cathode ray tube in order to study the fluorescent light given off by particular rarefied gases. The cathode ray was a glass tube with the air taken out of it. At one end of the tube is a cathode and at the other end is a metal target. In the cathode, a filament is heated and electrons flow towards the metal target. The electrons hit the atoms and nuclei in the metal target and X-rays, or Roentgen rays, are produced. Roentgen discovered that these rays made fluorescent screens glow, that lead created a shadow when placed between the ray and a screen whereas many other thin layers of material created no shadow, and that the rays actually allowed the skeletal system in bodies to produce shadows. Henri Becquerel's discovery of uranium's rays was an accident. Becquerel was trying to induce fluorescence, the production of rays such as Roentgen's rays in chemical compound by exposing them to sun rays. As he was about to test uranium, he noticed the sky was cloudy. Frustrated, he tossed the uranium and photo plates in his drawer. Four days later, he developed the plates and discovered the impression of a copper screen that was between the uranium and photo plates. Becquerel realized that the ability to produce X-ray like radiation was not induced by sun light but was an intrinsic property of uranium. Many scientists became fascinated by the newly found radiation with the property to cause a glowing effect and produce images on photo plates. Most scientists studied the X-rays from cathode ray tubes because they were stronger than the rays produced by uranium. In addition, the cathode ray tube was much easier to attain that uranium samples. The radiation interested Marie Curie as well, and the less studied Becquerel rays became her intriguing topic for doctoral research.

Paris Municipal School of Industrial Physics and Chemistry, where Pierre was professor of physics, permitted Marie to use a crowded, damp storeroom as a lab and, thus, Marie began her research on uranium. Instead of measuring the radiation by using photo plates, Marie used a device that Pierre and his brother had invented, the Curie electrometer. It measured the low electrical current produced when uranium collided with the air. Marie made a discovery that, although controversial at the time, would completely change the scientific understanding of atoms. Scientists at the time regarded the atom as the smallest, indivisible particle. Marie observed that the electrical effects of uranium's rays were constant, regardless of whether the uranium was solid or pulverized, pure or in a compound, wet or dry, or whether exposed to light or heat. The intensity of the rays was only altered by adding or subtracting the amount of uranium. The ability to emit radiation was a property of uranium. The radiation was actually the emission of tiny particles and energetic waves from the atom.

Marie's next experiment was to test all the other known elements and test for the ability to emit radiation. She found that thorium shared in uranium's ray emission. Giving a name to the behavior of uranium and thorium, she invented the word "radioactivity." Marie also tested compound and found that pitchblende, which contained uranium, gave off more radioactivity than uranium could account for. Marie began to hypothesis that a pitchblende may contain a new element; one yet to have been discovered. Pierre decided to put aside his own experiment so that Marie and he could work together. Both were excited to begin experimenting, despite the unfavorable working conditions of the storeroom lab and the fatigue and poor heath they experienced. The long exposure to radiation was beginning to affect their bodies.

Pitchblende had been studied before the discovery of radioactivity. A sampling could contain up to thirty different elements; if a new element was hidden in pitchblende, the element must be found in extremely small amounts. Also, since there was more radioactivity than uranium could account for, the new element would need to be extremely radioactive. They used chemical analysis to separate the different elements found in pitchblende. For example, a particular element may dissolve in an acid, which could then be poured off the top and separated from the rest of the pitchblende sample. The Curies would then use the Curie electrometer to identify the most radioactive fractions. In 1898, Marie and Pierre successfully discovered two new elements: polonium, named after the country of Marie's birth, and radium, from the Latin word for ray. There was still doubt in the minds of other scientists as to whether the elements existed. Neither polonium nor radium had been isolated completely. Marie and Pierre set out to separate polonium and radium from the bismuth and barium that the new elements remained attached to. The Curies moved to an abandoned shed in order to have more room. The shed, a former dissecting room for medical school, was plagued by poor outfitting and ventilation. Marie and Pierre would spend many days in the poor shed, excited by their work but growing increasingly weak in health. Although unable to obtain pure polonium, they obtained a sample of pure radium.

The world was fascinated by the Curies' discoveries: two new elements with fascinating properties. Radium possessed a natural glow, one which Marie and Pierre loved to see as they walked into the shed or from the small amount they carried with them. Pierre showed that radium could harm the skin. This property could be used for medical purposes, such as treating cancer. Industries were especially interested in radium's inexhaustible ability to give off energy and heat. Some scientists began using it for experimenting on atoms. Although Marie and Pierre continued to progress in their experiments, the pain, burns, and diminishing health were a continuing concern while dealing with radioactivity.

Despite all the success, the Curies still faced financial problems. Both Marie and Pierre worked jobs in addition to the hours they spent experimenting with radioactivity. Marie completed her doctoral thesis in 1903 and became the first woman to receive a doctorate in France. Also in 1903 Marie and Pierre were awarded the Nobel Prize "in recognition of the extraordinary services they have rendered by their joint researches on the radiation phenomena discovered by Professor Henri Becquerel" [1]. The couple's fame was growing and the publicity's interest and curiosity was increasing. Marie represented the strength of women. She made a point of revealing the lack of resources and support for scientists. But publicity can turn sour all too quickly; the Curie's lab work atmosphere was no longer quiet and distraction-free and privacy seemed to be a thing of the past. In fact, the press would be a continuous affliction in Marie's life. In addition to the prying eyes of the public, the Curies still had no appropriate laboratory to work in. Despite the new joy of Marie's second child Eve being born in 1904, tragedy struck in 1906 when Pierre slipped into a rainy street and was killed instantly by a horse-drawn wagon.

Marie became determined to build a laboratory in honor of Pierre. She continued her study of radioactivity, and in 1911 Marie won the Nobel Prize in Chemistry "in recognition of her services on the advancement of chemistry by the discovery of the elements radium and polonium, by the isolation of radium and the study of the nature of the compounds of this remarkable element" [1]. In 1914 the building of the long-awaited Radium Institute was almost completed, just in time for Marie's next endeavor: helping in the war effort. In 1914 Marie and her oldest daughter Irene took X-rays to the front lines of the war. They used the X-rays to detect bullets, shrapnel, and broken bones. Through generous donations, Marie equipped 20 vehicles with X-ray equipment so that the equipment could be easily transported. Also Marie collected radon, a radioactive gas emitted by radium, in glass tubes about one centimeter long. Doctors then used platinum needles to place the tubes directly in a soldier's body in order to destroy diseased tissue.

After the war ended in 1918 Marie resumed to her experimenting with radioactivity and devoted most of her time to the Radium Institute once it was completed in 1919. The research staff was diverse, with French, Poles, women, and others. Since the discovery of uranium's intrinsic ray producing property, the door was opened for many areas of study. By bombarding atoms with radiation, scientists learned about the structure of the atom, supporting Marie's discovery that the atom was divisible. Ernest Rutherford used radioactivity in order to study the nucleus of the atom. He first postulated in 1911 that the atom consisted of a small, massive nucleus surrounded by light-weight electrons. In 1932, Rutherford's colleagues discovered that the nucleus of an atom can be further divided into positively charged protons and electrically neutral neutrons. A surprising study was that of elements decaying into a different element just as in the ancient dreams of alchemists of the possibility of making gold. The unstable nucleus of some radioactive elements emits alpha particles consisting of two protons and two neutrons. Since elements are defined by their number of protons, the two lost protons change the atom into a new element. Alpha particles continue to be emitted until a stable nucleus is formed. The study of quantum mechanics, which would be used to understand radioactivity, greatly improved due to the increased knowledge of the atom's composition. Quantum theory is the study of phenomena involving small objects, generally of atomic size or smaller. From 1900's to 1930's quantum mechanics, or the study of the motion of small particles, was developed.

Marie’s oldest daughter Irene and her son-in-law Frederic Joliot discovered artificial radioactivity while in the Radium Institute in 1934. Marie’s radioactivity also led to much advancement. The treatment of cancer was improved by using radiation. The radiation could be specifically directed towards the cancerous area in order to attack and destroy the cancer. Dating techniques in biology, physiology, geology, and archeology became based on radioactive decay. Radioactive atoms have specific half-lives. A half-life is determined by how much time it would take a radioactive atom to lose enough alpha particles such that the nucleus is half its initial size. For example, the half life of Marie Curie's polonium is 138 days. Half of the nucleus has decayed in 138 days. After another 138 days, the nucleus is one fourth its initial size. Marie was unable to isolate polonium from a sample of pitchblende because, during the process of chemical analysis, the polonium had almost disappeared due to its short half life. Another important area of study surfaced as a result of Marie's work. Once the nucleus and its components were discovered, the study of nuclear energy was introduced. Nuclear energy is defined as the energy that holds together the particles that compose the nucleus of an atom. When an element is radioactive, some of the nuclear energy is released as radiation. It was discovered that the radiation was composed of electromagnetic waves or energetic particles—such as protons or neutrons—or both waves and particles. The radioactivity is either spontaneous or induced by external bombardment. Two types of nuclear energy are fission, when a very heavy nucleus splits and discovered in the 1930's, and fusion, when two light-weight nuclei combine. The concept of nuclear reactors developed in the early 1940's. The first important application of fission was the end of World War II when the atomic bomb exploded over Japan. The atomic bomb was used as a trigger in the 1950's for a fusion bomb, or hydrogen bomb, thus achieving uncontrolled fusion. Despite ill health, finances, and prejudices, Marie Curie had determination and persevered in her experiments with radioactivity. Marie's experiments led to the many advances that affect our life today, such as the advances in physics theory, cancer treatment, dating techniques, and nuclear energy.

References

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