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2011—The year of Maria Skłodowska-Curie: A woman for eternity, but a Polish woman of her time

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"At the centenary of awarding Maria Skłodowska-Curie the Nobel Prize in chemistry for the discovery of the new elements polonium and radium, the Polish Sejm decided to pay homage to one of the greatest scientists of our time, whose groundbreaking discoveries have contributed to the global development of science; Poland's Senate establishes 2011 as the Year of Maria Skłodowska-Curie, in order to promote awareness of her great contribution to the development of global science, and her attitude saturated with the deepest of humanity" wrote in the project of the resolution in the matter establishment of the year 2011 Maria Year Skłodowskiej-Curie. On 3 December 2010, the Polish Sejm, and on 27 January 2011, the Polish Senate, passed a resolution on establishing 2011 as the Year of Maria Skłodowska-Curie.

Year 2011 is the also International Year Chemistry IYC2011 proclaimed by the United Nations, with events being coordinated by UNESCO and IUPAC, and coinciding with the 100th anniversary of the Nobel Prize awarded to Maria Skłodowska-Curie – an opportunity to celebrate the contributions of women to science. This year also marks 100th anniversary of the founding of the International Association of Chemical Societies, of which The International Union of Pure and Applied Chemistry is the direct successor.

The Polish Chemical Society is the main organizer of the events of the IYC2011 in Poland. Maria Skłodowska-Curie was its founder in 1919 and Honourable Member since 1924.

Maria Skłodowska-Curie (Fig. 1) is the only scientist in history to receive the Nobel Prize twice, once in physics (1903) for the discovery of radioactivity and once in chemistry (1911) for the discovery of polonium and radium and studies concerning the nature of these elements. Scientific work, which she started together with her husband Pierre Curie and continued after his death, opened a new sphere of physics and chemistry and led to the development of the first methods of studying the interior of the atom and the nature of matter. These studies have dominated contemporary science. Stating that radiation of radioactive substances induces chemical reactions, she became the founder of radiochemistry. She was able, in a very fast way, to introduce her scientific theories and check them out in practice. She was asked to write autobiography . . .

"It will not be much of a book. It is such an uneventful, simple little story. I was born in Warsaw, in professors family, I married Piotr Curie, I had two children. My scientific work I made in France"

Maria Salomea Skłodowska was born in Warsaw, Poland, on 7 November 1867, the fifth and youngest child of well-known teachers Bronisława and Władysław Skłodowski. Maria's older siblings were Zofia (born 1862), Józef (1863), Bronisława (1865), and Helena (1866). Her father Władysław Skłodowski taught mathematics and physics, subjects that Maria was to pursue, and he also was the director of two Warsaw high schools for boys. Her mother, Bronisława, operated a prestigious Warsaw boarding school for girls. When Maria was 10 years old, she began attending the boarding school, next Maria attended a junior high school for girls, from which she graduated with the gold medal on 12 June 1883. She spent the following year in the countryside with her father's relatives, and later with her father in Warsaw, where she did some tutoring. On both the paternal and maternal sides, the family had lost their property and fortunes because of their patriotic involvement in the Polish national uprisings. This condemned each subsequent generation, including Maria's and her siblings', to a difficult struggle to get ahead in life. At the end of the 1880s, Maria was engaged in clandestine patriotic activity of Polish youth teaching peasant children the Polish language, history, and algebra, under danger of being sent into exile in Siberia, because Russia ruled this part of Poland at the time. Maria made an agreement with her sister, Bronisława, that she would give her financial assistance during Bronisława's medical studies in Paris, in exchange for similar assistance 2 years later. In connection with this, Maria took a position as a governess for nearly 3 years in small village Szczuki with a landed family, the Żórawskis, who were relatives of her father. While working for them, she fell in love with their son, Kazimierz Żórawski, who felt the same for her. His parents, however, rejected the idea of his marrying the penniless relative and Kazimierz was unable to defy them. As a result of this, Maria lost her position as the governess. At the beginning of 1890, Bronisława, a few months after she married Kazimierz Dłuski, invited Maria to join them in Paris. Maria declined because she could not afford the university tuition and

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Fig. 1. Maria Skłodowska-Curie (1867–1934).

was still counting on marrying Kazimierz Żórawski. She returned home to her father in Warsaw where she remained until the fall of 1891. She tutored, studied at the clandestine Floating University, and began her practical scientific training in a laboratory at the Museum of Industry and Agriculture at Krakowskie Przedmieście 66, near Warsaw's Old Town, and under the direction of Professor Napoleon Milicer and Doctor Ludwik Kossakowski, perfected skills of qualitative and quantitative analysis with regard to the basics of the extraction and crystallization. She remembered this period later as the most essential for the achievement by her successes: "*If prof. N. Milicer and Dr L. Kossakowski didn't teach me analytical chemistry, I would never isolated polonium and radium . . .*" (Fig. 2).

In November 1891, Maria went to Paris and she quickly found shelter with her sister Bronisława and brother-in-law Kazimierz Dłuski before renting a primitive garret and proceeding with her studies in physics, chemistry, and mathematics at the Sorbonne (the University of Paris). Skłodowska studied during the day and tutored in the evenings, barely earning her keep. On 28 July 1893, she was awarded a degree in physics and began work in an industrial laboratory at Lippman's. Meanwhile she continued studying at the Sorbonne and in July 1894 earned a degree in mathematics. After 3 years she had passed, brilliantly, examinations in physics and mathematics.

In 1894, Maria met Pierre Curie. He was 35 years old, 8 years older than she and was an internationally known physicist. He was an instructor in the School of Physics and Chemistry, the Ecole Superieure de Physique et de Chimie Industrielles de la Ville Paris (ESPCI).

They made friends both very much, but Maria planned the return to the homeland. She, however, did not find the possibility of the scientific work here. The gates of national universities stood before her closed. There was no place for scientific work for women on the contemporary Polish grounds. She was informed that in Poland under annexation it will not change, and the long parting with Pierre helped her to perceive that "*each of us understood that we would not find the better companion of the life*". On 26 July 1895, Maria Skłodowska and Pierre Curie married, and thereafter the two physicists hardly ever left their laboratory. Maria had found a new love, a partner, and a scientific collaborator on whom she could rely. Their first daughter Irène was born on 12 September 1897, and the second one, Ève, on 6 December 1904 (Fig. 3).

After the marriage, in 1895 Maria began independent investigations over the then new problem of radioactivity. From 1900, Maria had a part-time teaching post at the École Normale Superieur de Sevres for Girls. After thousands of crystallizations she finally isolated one decigram of almost pure radium chloride and had determined radium's atomic weight as 225. She presented the finding of this work in her doctoral thesis. On 25 of June 1903, under the supervision of Henri Becquerel, Maria was awarded her PhD from the University of Paris for her thesis entitled "Research on Radioactive Substances". The examination committee: Gabriel Lippmann, Henri Moissan, and Edmond Bouty, expressed the opinion that the findings represented the greatest scientific contribution ever made in a doctoral thesis (Fig. 4).

In the same year, 1903, the Royal Swedish Academy of Sciences awarded Pierre Curie, Maria Curie, and Henri Becquerel the Nobel Prize in Physics, "in recognition of the extraordinary services they have rendered by their joint research on the radiation phenomena discovered by Professor Henri Becquerel." Skłodowska-Curie and her husband were unable to go to Stockholm to receive the prize in person, but they shared its financial proceeds with needy acquaintances, including students. As a result of the Nobel Prize, Maria and Pierre Curie suddenly became internationally famous. On 1 October 1904, the Sorbonne gave Pierre a professorship and permitted him to establish his own laboratory, in which Skłodowska-Curie became the director of research. On 19 April 1906, Pierre was killed in a

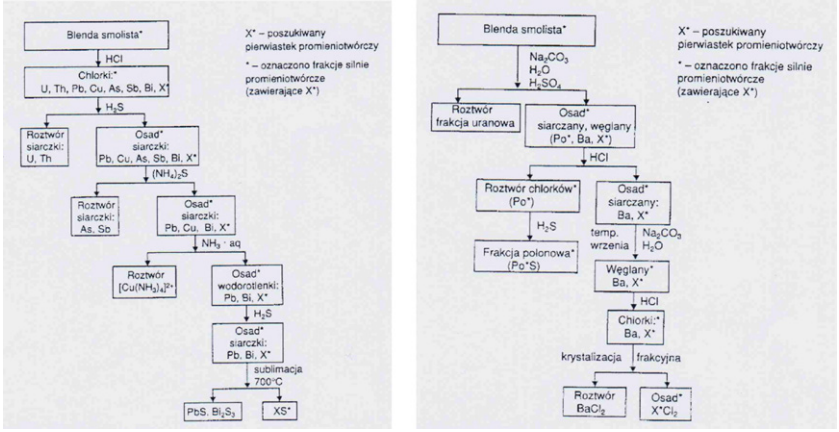

Fig. 2. The schemes for the isolation of polonium and radium.

Fig. 3. Maria and Pierre's honeymoon trip (1895).

Fig. 5. Maria Skłodowska-Curie in the laboratory.

street accident, he was run over by a horse-drawn wagon near the Pont Nuef in Paris. Maria was devastated by the death of her husband, she was left alone with two daughters, Irène aged 9 and Ève aged 2 (Fig. 6). Maria noted that, as of that moment, she suddenly had become "an incurably and wretchedly lonely person". She was appointed to succeed Pierre as the head of the laboratory, being undoubtedly the most suitable person, and to be responsible for his teaching duties. On 13 May 1906, the Sorbonne Physics department decided to retain the chair that had been created for Pierre Curie and they entrusted it to Skłodowska-Curie together with full authority over the laboratory. This allowed her to emerge from Pierre's shadow. On 16 November 1908, Maria was the first woman to become a professor at the Sorbonne, and in her exhausting work regime she sought a new meaning in her life. She went on to produce four decigrams of very pure radium chloride and determined radium's precise atomic weight as 226.45 ± 0.5 (now 226.025) (Fig. 5).

In 1911, Maria Skłodowska-Curie was awarded the Nobel Prize in Chemistry (Fig. 7). The citation by the Nobel Committee was, "in recognition of her services to the advancement of Chemistry by the discovery of the elements radium and polonium; by the isolation of radium and the study of the nature and compounds of this remarkable element". Maria's Nobel lecture on December 11 in Stockholm

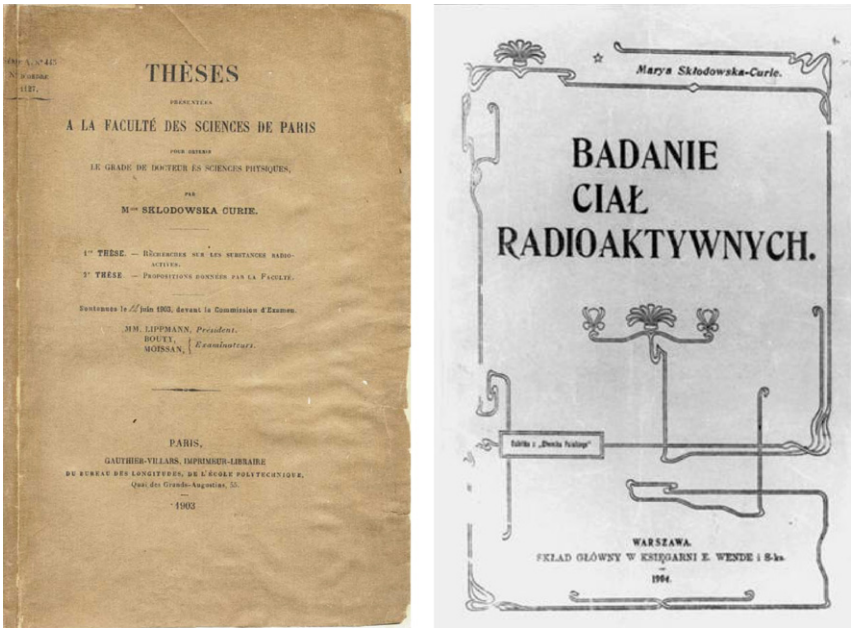

Fig. 4. The title page of the French (1903) and Polish (1904) editions of Maria Skłodowska-Curie's doctoral thesis.

Fig. 6. Maria Skłodowska-Curie with daughters: elder Irene and younger Eve (1906).

should be read in the light of what she had gone through. She made it clear by her choice of words what were unequivocally her contributions in collaboration with Pierre. She spoke of the field of research which, "*I have called radioactivity*" and "*my hypothesis that radioactivity is an atomic property*" but without detracting from his contributions. She declared that she also regarded this Prize as a tribute to Pierre Curie. The French government funded the building of a private Radium Institute (now the Institut Curie), which was built in 1914 and at which research in chemistry, physics, and medicine was conducted.

Despite the second Nobel Prize and an invitation to the first Solvay Conference with the world's leading physicists, including Einstein, Poincaré, and Planck, 1911 became a dark year in Maria's life. In two smear campaigns she was to experience the chauvinism of the French press. The first campaign was started on 16 November 1910, when, in an article in Le Figaro, it became known that she was willing to be nominated for election to l'Académie des Sciences (Fig. 8).

Fig. 7. The certificate for the Nobel Prize awarded to Maria Skłodowska-Curie on 10th December 1911.

Fig. 8. Maria Curie was the only woman in attendance at the first Solvay Conference, held in Brussels, Belgium, in November 1911.

In 1914, Maria was in the process of beginning to lead one of the departments in the Radium Institute established jointly by the University of Paris and the Pasteur Institute. In August 1914, Germany invaded France. During the war Maria, with the help of her daughter Irène, pushed for the use of mobile radiography units, which came to be popularly known as petites Curies ("Little Curies"), for the treatment of wounded soldiers and she was engaged intensively in equipping more than 20 vans that acted as mobile field hospitals and about 200 fixed installations with X-ray apparatus. At the Radium Institute she prepared tiny glass tubes containing a radioactive gas (radon) that comes from minerals containing radium. Hospital doctors inserted the tiny tubes into patients at spots where the radiation would destroy diseased tissue. Maria trained young women in simple X-ray technology, she herself drove one of the vans and took an active part in locating metal splinters.

In 1918, The Radium Institute, the staff of which Irène had joined, began to operate in earnest, and it was to become a universal centre for nuclear physics and chemistry. Maria Curie, from 7 February 1922, a member of the Academy of Medicine, devoted her research to the study of the chemistry of radioactive substances and the medical applications of these substances.

In 1921, Maria Skłodowska-Curie, accompanied by two her daughters, was welcomed triumphantly when she toured the United States to raise funds for research on radium. These distractions from her scientific labors and the attendant publicity caused her much discomfort but provided resources much needed for her work. The prominent American female journalist Marie Maloney organized further collections for one gram of radium for an institute which Maria had helped found in Warsaw. Thanks to the press coverage, Maria became enormously popular in America, and everyone seemed to want to meet her – the great Madame Curie. During her second American tour in 1929, President Warren Harding presented her with a gram of radium bought as the results of a collection by American women. This radium was successful in equipping the Warsaw Radium Institute, founded in 1925 with her sister, Bronisława, as director (Fig. 9).

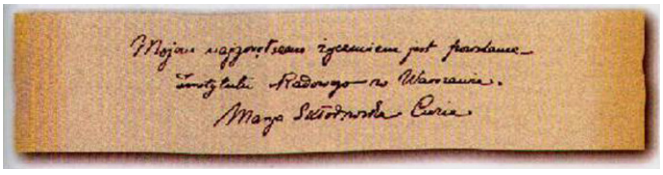

Fig. 9. "...my heartiest wish is to build a Radium Institute in Warsaw..." (1924).

In her later years, Maria Skłodowska-Curie headed the Pasteur Institute and a radioactivity laboratory created for her by the University of Paris. She continued to do research on radioactivity, but her main focus shifted to running the Radium Institute. She made the Institute a centre for measuring the radium content of various products used by doctors and others. She also made it a world centre for research, carefully selecting several dozen scientists and keeping up with the progress of each. Her researchers made many discoveries. In the last 10 years of her life, Maria had the joy of seeing her daughter Irène and her son-in-law Frédéric Joliot carry out successful research in the laboratory. She lived to see their discovery of artificial radioactivity, but not to hear that they had been awarded the Nobel Prize in Chemistry for it in 1935. Maria Skłodowska-Curie visited Poland for the last time in the spring of 1934 and, only a few of months later, she died on 4 July 1934 at the Sancellemoz Sanatorium in Passy, in Haute-Savoie, eastern France, from aplastic anemia (leukemia), almost certainly contracted from exposure to radiation. The damaging effects of ionizing radiation were not then known, and much of her work had been carried out in a shed, without proper safety measures. She had carried test tubes containing radioactive isotopes in her pocket and stored them in her desk drawer, remarking on the pretty blue–green light that the substances gave off in the dark. She was interred at the cemetery in Sceaux, alongside her husband Pierre. Maria Skłodowska-Curie and Pierre Curie's pioneering research was again brought to the fore when on April 20, 1995, their bodies were taken from their place of burial at Sceaux, just outside Paris, and in a solemn ceremony were laid to rest under the mighty dome of the Panthéon. Maria Curie thus became the first woman to be accorded this mark of honour on her own merit. It was François Mitterrand, President of France, who took this initiative, as he said "*in order to finally respect the equality of women and men before the law and in reality*". In point of fact – as the press pointed out – this initiative was symbolic three times over. Maria Skłodowska-Curie was a woman, she was an immigrant, and she had to a high degree helped increase the prestige of France in the scientific world.

In 1967, in the 100th anniversary of Maria Skłodowskiej-Curie's birthday, the Museum that consecrated her was created. It is located in Warsaw at Freta 16 street, in the building in which she was born. There are valuable collections of objects belonging to Maria, photos, and documents illustrating her exceptional life and achievements (Fig. 10). This building is also headquarters of the Polish Chemical Society.

Some of the achievements and contributions of Maria Skłodowska-Curie to life, science and the progress of civilization are summarized briefly below:

1. Her biography is an example for others
   - Physics – she showed that this science was also for women
   - Way from devotion to success
   - Way from scientific discoveries to their implementation
2. Construction of new instruments
3. Development of new research methods
4. Introduction of the concepts and physics of radioactivity
5. Launch of new scientific disciplines
   - Medical physics
   - Radiotherapy
   - Nuclear chemistry
6. Discovery of two new elements, polonium and radium
7. Creation of new scientific therapeutic units – Radium Institutes in Paris and Warsaw, the creation of the Radiological Laboratory in Warsaw
8. Received two Nobel Prizes in two different fields of science, physics and chemistry

Fig. 10. Maria Skłodowska-Curie Honourable Member Diploma of Polish Chemical Society (1924).

Maria decided to begin the research on scientific work of Henry Becquerel. She considered Becquerel rays as a possible field of study. She began by carefully repeating Becquerel's experiment with the uranium compounds, measuring their ionization efficiencies. She measured the strength of radiation and drew a conclusion that the radiation came from the interior of atoms. This discovery revolutionized modern physics and it attracted scientist's attention on the internal structure of atoms.

Maria Skłodowska-Curie, along with her husband Pierre, discovered two new radioactive chemical elements: polonium and radium. The Curies qualitatively isolated both of these elements, while Marie later obtained them in their pure states, *thanks to her knowledge of analytical chemistry techniques of the time.* The Curies were the first to use radioactivity as a tool for isolating new chemical elements from a complex matrix. Maria was the founder of radiochemistry – the chemistry of radioactive elements. She also found that the radiation emitted from radioactive substances causes chemical reactions, a discovery that represents the birth of radiation chemistry. She provided the information required to replicate her process for isolating radium and polonium to interested scientists and commercial producers free of charge. After isolating polonium and radium, much of her research was directed towards the use of radioactive substances in medicine – mainly in diagnostics and for curing cancer (so her childhood dream came true). Without her pioneering work, the history of atomic and nuclear research would be very different. For example, in 1909, Ernest Rutherford with his co-workers H. Geiger and E.G. Marsden used a sample of radium to bombard a thin gold foil with alpha particles. In 1911, the data he obtained from this experiment led him to formulate the planetary model of the atom – a model that is still valid (with some refinements) today. In 1919, by bombarding nitrogen atoms with alpha particles, Rutherford carried out the first artificial nuclear reaction.

Maria Skłodowska-Curie is the beautiful and splendid example of the Polish contribution to the European science and our participation there. The great scientist became one of the most well-known figures in Poland and in the World. Universities, schools,

Fig. 11. Maria and Pierre Curie (1904).

Centre Oncology, many streets and squares in the whole world carry her name. Many monuments and museums are dedicated to her. She has honourable citizenship of Warsaw. She remained for Poles the symbol of the personality with the highest moral value and the highest scientific qualifications. In memories of these, for many friends who had happiness to be together with her at work, to spend the free time with her, she remained as the exceptional personality, and also heroic and dramatic (Fig. 11).

Albert Einstein said, "Marie Curie is, of all the famous people, the one whom fame has not corrupted".

Further reading

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The International Year of Chemistry 2011 coincides with the 100th anniversary of the Nobel Prize awarded to Maria Skłodowska-Curie for the discovery of polonium and radium. Her success was in part due to her training in analytical chemistry for performing separations, as she pointedly states. Professor Boguslaw Buszewski (President of the Polish Chemical Society and of the European Society of Separation Science) and his colleague Monika Michel (Secretary General of the Polish Chemical Society) from Poland, Maria's birth country, have prepared a special historical account of her life and achievements, very relevant for our series on analytical chemistry in this International Year of Chemistry 2011. It is fascinating reading.
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