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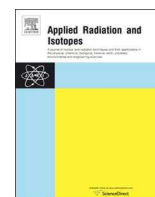
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Marie Curie, the international radium standard and the BIPM

Céline Fellag Ariouet

International Bureau of Weights and Measures, BIPM, Sèvres and Archives Poincaré, University of Lorraine (France)

1. Introduction

This year marks the 60th anniversary of the decision that led to the establishment of the Ionizing Radiation Department, then the Ionizing Radiation Section of the International Bureau of Weights and Measures (BIPM). Since 1960, the BIPM has been maintaining the international reference standards for dosimetry and activity measurements for the world-wide community.

This was preceded two years before by the establishment of the Consultative Committee for the Standards of Measurement of Ionizing Radiation (CCEMRI) which was set up to initiate a programme of work for the BIPM in the field of ionizing radiation and to make plans in terms of staffing and materials required for its implementation. The aim was to enable the BIPM to run international comparisons of standards in order to coordinate the global measurement system. The CCEMRI (the name was changed to Consultative Committee for Ionizing Radiation (CCRI) by the International Committee for Weights and Measures (CIPM) in 1997) met for the first time on 13 April 1959.

Less well known is that a few decades ago, the BIPM was given the role of being the custodian of the international radium standard. Marie Curie and her radium standard have therefore shared a common history with the BIPM, established in 1875 by the Metre Convention.

2. Marie Curie

As the first woman to teach at the École Normale Supérieure in Sèvres, the first woman to obtain a professorship at the Sorbonne in Paris, and the only woman to date to receive two Nobel Prizes, Marie Curie is a major figure of the 20th century. Albert Einstein said about her

Marie Curie is, of all celebrated beings, the only one whom fame has not corrupted.

Marie Curie is a symbol, that of perseverance and excellence when science was no longer a profession but a vocation, and the symbol in particular of scientific selflessness that marked the history of radium. Marie Curie and Pierre Curie consciously waived a huge fortune and decided to never apply for a patent for their discovery of radium, so that its benefits could be shared by all for the common good (Coursey, 2017). Marie Curie never regretted that decision. However, as she was fully aware of the sacrifices and difficulties it implied, she participated in 1922 in the drafting of a resolution aimed at protecting scientific discoveries made during her work with the International Commission on Intellectual Cooperation created by the League of Nations.

Maria Skłodowska was born in Warsaw in 1867. She left Poland in 1891 to study physics at the Sorbonne in Paris. She married Pierre Curie in 1895: they jointly announced in 1898 their discovery of two new elements: radium and polonium.

Pierre and Marie Curie received the Nobel Prize in Physics for this discovery that was shared with Henri Becquerel for his work on radioactivity.

In 1911, Marie Curie was awarded the Nobel Prize in Chemistry in recognition of her work on the nature and compounds of radium.

Between 1900 and 1906, Marie Curie was professor of physics at the École Normale Supérieure in Sèvres where she had a laboratory. She gave a new impetus to physics teaching, in particular by introducing experimental work and bringing to the school instruments she had created to use with her students. At the École Normale Supérieure, she taught two courses of one and a half hours per week (The CIEP and its history). This women's teacher training college was housed from the end of 19th century to 1940 in the buildings of the Royal Sèvres Porcelain factory commissioned by Louis XV in 1756. It is now known as 'France Education International' and it is situated a hundred metres from the BIPM.

Marie and Pierre Curie were close friends of Charles-Edouard Guillaume (1861-1938) who joined the BIPM in 1883. Director of the BIPM between 1915 and 1936, he was awarded the Nobel Prize in Physics in 1920 for his research on nickel-iron alloys. He met Pierre Curie at the French Physics Society when he joined around 1889. Over the years, he became a close friend of the Curie family. It was at this time that Marie Curie visited the International Bureau of Weights and Measures located in the vicinity of the École Normale where she was teaching physics. She appears on two BIPM photographs dated from around 1904. On the first photograph (Fig. 1), she was surrounded by her family, with Pierre Curie, his father and her daughter, and with Charles-Édouard Guillaume who was then Deputy Director of the BIPM and his family.

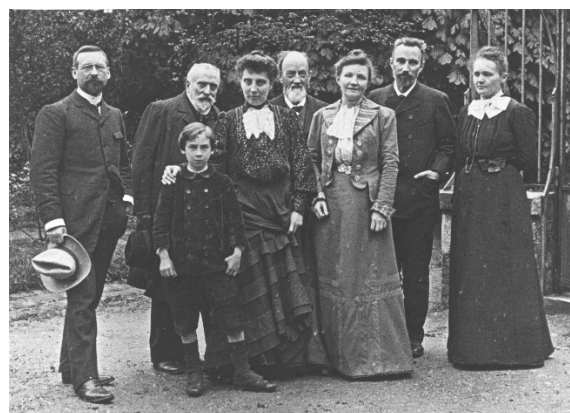


Fig. 1: Charles-Édouard Guillaume, Dr Tripier, Maurice Guillaume, Mrs Guillaume, Dr Curie, Ms Hélène Dubois (physics teacher in Sèvres), Pierre and Marie Curie (around 1904, at the entrance of the BIPM), © Musée Curie

The second photograph (Fig. 2) was taken in front of the entrance to the BIPM by Charles-Édouard Guillaume.



Fig. 2: Marie Curie, Pierre Curie, his father and Irène Curie at the BIPM in 1904 ©Musée Curie

When Pierre Curie died in 1906 in a traffic accident in Paris, Marie Curie decided to continue his work and teaching. The Faculty Council of the Sorbonne proposed that Marie Curie take over Pierre Curie's chair at the Sorbonne.

In 1910, Marie Curie published the Treaty of radioactivity that gathered knowledge on radioactivity and included, for example, a table with all the known radioactive elements. In 1910, in collaboration with André Debierne, she isolated metallic radium. From 12 to 15 September 1910, the Radiology Congress met in Brussels in conjunction with the Universal Exhibition which had been taking place since 23 April 1910.

At this Congress, where most of the eminent scientists in the field of radioactivity met, the need to produce reference standards to be used for comparisons in different laboratories was discussed for the first time.

A result of these discussions was the creation of the International Radium-Standards Commission composed of ten members: E. Rutherford¹ (President), M. Curie, O. Hahn, F. Soddy², B. Boltwood, A. Debierne, A.S. Eve, H. Geitel, S. Meyer (Secretary) and E. Schweidler. The first task of the Commission was to prepare a radium standard. The multiplication of laboratory standards made it necessary to adopt an international standard as a reference (Boudia, 1993). The international standard would enable each State to own a radium standard which could be compared directly with the international standard. It was of course very important for measurements which

would become reliable and traceable both for commercial and health applications. Marie Curie who had acquired significant experience in the preparation of radioactive sources was the best scientist to undertake this task.

3. The preparation of the international standard

The first sample was prepared by Marie Curie in August 1911 (Curie, 1912), the other standards were prepared by Otto Hönigschmid in Vienna. The samples were prepared using anhydrous chloride, as pure as possible: the preparation made by Marie Curie contained 21.99 mg of the purest radium chloride, from the material used for the determination of the atomic weight of radium. The Marie Curie standard (Fig. 3) was sealed in a very narrow and thin glass tube with walls of 0.27 mm thickness, 1.46 mm inner diameter, 0.9 mm interior diameter and 32 mm length. Marie Curie explained that the bottom of the tube had been stretched and closed with a lamp on a very thin platinum wire that extended to the inside of the tube (Curie, 1912).

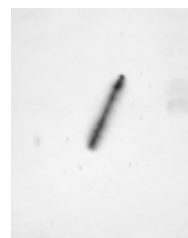
Three standard preparations were also produced at the Institute for Radium Research of the Academy of Sciences in Vienna that had a 0.27 mm glass thickness, 3.0 mm inner diameter and 32 mm length. They respectively contained 10.11, 31.17 and 40.43 mg of RaCl_2 as pure as possible. The Parisian and Viennese preparations were made of pitchblende originating from St Joachimstal and were practically free of mesothorium (Rutherford, 1912). As highlighted by André Allisy (Allisy, 1994):

The first unit used in radioactivity was the unit of mass, as the radium standards were defined by the mass of radium regardless of its state of chemical combination, contained in sealed glass tubes.

As from the end of 1911, Marie Curie suffered from a serious kidney disease. After she prepared the radium standard, she was unable to proceed with the comparisons. She was also reluctant that the radium standard should become the property of the Commission and be kept outside of her institute. The International Radium-Standards Commission met from 25 to 28 March 1912 in Paris, at the Chatham hotel and in the laboratory of Prof. Lipmann for the measurement. The Commission decided that a comparison of the emitted radiation would be carried out with the radium samples of the highest purity produced and weighed with utmost precision. The comparison took place at La Sorbonne where Prof. Lipmann had a room uncontaminated by radium. André Debierne set up an installation at this site in order to compare the γ -rays of the standards by two different methods: the method employed at the Curie laboratory using the piezoelectric quartz of Pierre Curie and the method recently developed by Rutherford and Chadwick (Rutherford, 1912). After the comparisons, which showed that the Paris and Vienna standards "agreed perfectly with one another within the limits of error of the measurements", the Commission accepted Marie Curie's standard as the International Radium Standard.



Fig. 3: Representation made by Marie Curie of the thin glass tube containing the International Radium Standard (Curie, 1912)



¹ Ernest Rutherford (1871 Brightwater, New Zealand - 1937 Cambridge, UK) was a New Zealand-born British physicist and chemist who came to be known as the father of nuclear physics. He discovered alpha and beta radiations and proved that radioactivity involved the nuclear transmutation of chemical elements. He was awarded the Nobel Prize in Chemistry in 1908 for this discovery.

² Frederick Soddy (Eastbourne 1877 - Brighton 1956) received the Nobel Prize in Chemistry in 1921 "for his contributions to our knowledge of the chemistry of radioactive substances, and his investigations into the origin and nature of isotopes".

Fig. 4 Glass tube with radium standard prepared by Marie Curie (1925),
Source © Musée Curie, Institut du Radium.

The International Radium-Standards Commission decided, as reported in the minutes of the meeting³, that the Director of the International Bureau of Weights and Measure, Prof. Benoît, should be asked to keep the international standard. It is also noted in several papers, among them a paper published by Ernest Rutherford in *Nature* (Rutherford, 1912) and in the paper written by Marie Curie in 1912 (Curie, 1912). Even before the meeting, an article published in a French newspaper, *Le Temps*, indicated:

The small radium tube which will serve as the international standard is likely to be deposited at the Bureau International des Poids et Mesures (BIPM). (Le Temps, 23 March 1912)

4. The BIPM, first custodian of the radium international standard

Before Stefan Meyer⁴, as Secretary of the Commission, officially wrote to the Director of the BIPM on 14 April 1912, to ask the Director of the BIPM to keep the standard and to define the practicalities for the deposit of the international standard at the BIPM, André Debierne⁵ had informally written on 18 March 1912, before the meeting of the Commission, to Charles-Édouard Guillaume for him to consider if the radium could be kept at the BIPM. The neutrality of the BIPM was a strong point:

In order to avoid having to choose between the different radioactivity laboratories, I think it would be a good idea to be able to deposit it with the International Bureau of Weights and Measures.

(Letter from André Debierne to Charles-Édouard Guillaume, 18 March 1912, BIPM Archive)

Debierne's request was welcomed by Guillaume who immediately managed to get a principle agreement from Justin-Mirande René Benoît (1844-1922) who was then Director of the BIPM. Guillaume replied on 21 March to Debierne to confirm the approval, provided that

the packaging is made in such a way as to avoid any liability.

(Letter of Charles-Édouard Guillaume to André Debierne, 21 March 1912, BIPM Archive)

Guillaume's letter also made it clear that the BIPM would keep the international radium standard unofficially and it outlined explicitly the boundary conditions for custody. In this respect, his principle agreement was given provided that no specific installation or arrangement would be required and that the BIPM would not be requested to engage in work to organize any comparison in its premises. Radioactivity measurement was not in the scope of the activity of the BIPM: Benoît and Guillaume did not want to ask for permission from the CIPM and warned Debierne:

If we have to provide facilities for the comparison of this standard with others, we will necessarily have to renounce to it. Indeed, such an organization could only be authorized by the International Committee for Weights and Measures, after consideration in its session, and it is infinitely likely that the decision would be unfavourable, since the matter is completely outside the scope of the Metre Convention.

(Letter of Charles-Édouard Guillaume to André Debierne, 21 March 1912, Archive BIPM)

Following the first exchange, the BIPM received the official

request from Meyer. Benoît replied with a long letter a few days after, confirming that he agreed in principle but informed Meyer that considering the importance of the international radium standard, he had to inform Wilhelm Foerster (1832-1921), President of the CIPM and Pietro Blaserna (1836-1918), Secretary of the CIPM. Foerster and Blaserna both replied positively. Foerster asked only if measures should be taken to protect the prototypes of the kilogram which could be placed next to the radium standard. In this letter, Benoît requested a procedure to define the rules regarding the standard; he also strongly expressed his concern about the publicity around the radium standard and requested the Commission, for security reasons, to keep confidential "without noise or promotion" the deposit of the international standard at the Pavillon de Breteuil.

Our Bureau holds great wealth, and in particular - with the international prototypes and their witnesses, with our divisional copies and various pieces in platinum or platinum-iridium - it contains considerable values in precious metals (...).The Pavillon de Breteuil, isolated, separated by a fairly large distance from the nearest dwellings, is enclosed in the Saint-Cloud Park, which is insufficiently guarded and protected. It is certainly in our interest to maintain this ignorance which is our safest protection. As far as the present case is concerned, it is quite certain that the removal of a few milligrams of radium salt is not propitious, in spite of the very high price of this material, to tempting a thief; but I consider it no less unfortunate to take this opportunity of drawing attention to the Pavillon de Breteuil as a place particularly designed to receive the deposit and custody of precious and valuable objects. Too much has already been said in newspaper articles published about the recent meeting of the Radium Commission. All that is needed is that the scientists interested in the matter be aware of it.

(Letter of J.-René Benoît to Stefan Meyer, May 1912, BIPM Archive)

For this reason, no publicity was made subsequently around the presence of the International Radium-Standard or by the BIPM. Once the approval of Foerster and Blaserna was received, the agreement was confirmed to the Commission.

Since Marie Curie had determined the radium standard using radium that belonged to her, it was decided that she would be provided first with an equivalent amount of radium. This is why almost a year passed before the Commission deposited the standard in the BIPM safe. The sample delivered to Marie Curie to replace her preparation was prepared by O. Hönlischmid in Vienna. It is interesting to note that the cost of the radium was borne by Sir George Beilby and his spouse, the parents in law of Frederick Soddy (Rutherford, 1912).

Marie Curie had an almost sentimental attachment to her radium. Thanks to the efforts of E. Rutherford, she finally agreed with the members of the Commission that the international standard will be the property of the Commission and will be deposited at the BIPM. This decision was certainly difficult for her but without doubt, the friendship between Charles-Édouard Guillaume and Marie Curie, which was reflected in their letters, played an important role because Marie Curie would have never accepted to part with her radium without full trust.

Marie Curie and André Debierne deposited the international radium standard at the BIPM on 21 February 1913 (fig. 5).

³ Minutes of the International Radium Commission written by Stefan Meyer, Archives BIPM.

⁴ Stefan Meyer who was Secretary of the Radium International Commission, was elected President of the Commission after Ernst Rutherford passed away in 1937.

⁵ André-Louis Debierne (1874-1949) was credited for the discovery of actinium, a radioactive element, in 1899. In 1912, he joined the new Curie Laboratory and the Radium Institute. He was one of the closest collaborators with Marie Curie until her death.

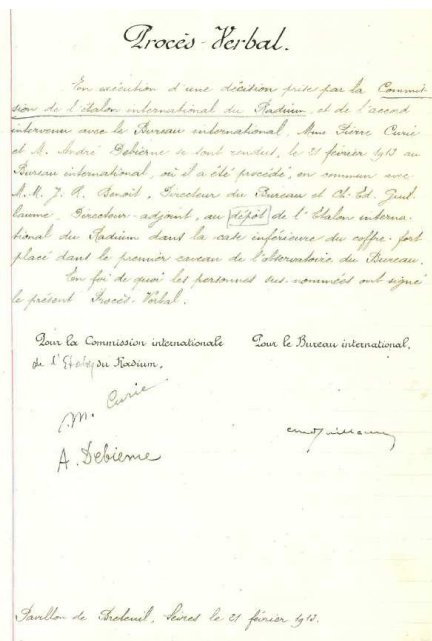


Fig. 5: Procès-verbal concerning the deposit of the international standard of radium at the BIPM, signed by Marie Curie, André Debierne and Charles-Édouard Guillaume, BIPM Archive.

In the following days, Charles-Édouard Guillaume took an active part in drawing up the rules for the conservation, removal and return to the safe of the radium international standard in close collaboration with Marie Curie and André Debierne. He suggested amendments to the articles 2 and 5 of the rules, which were fully accepted both by Marie Curie (Fig. 6) and Ernest Rutherford (Fig. 7).

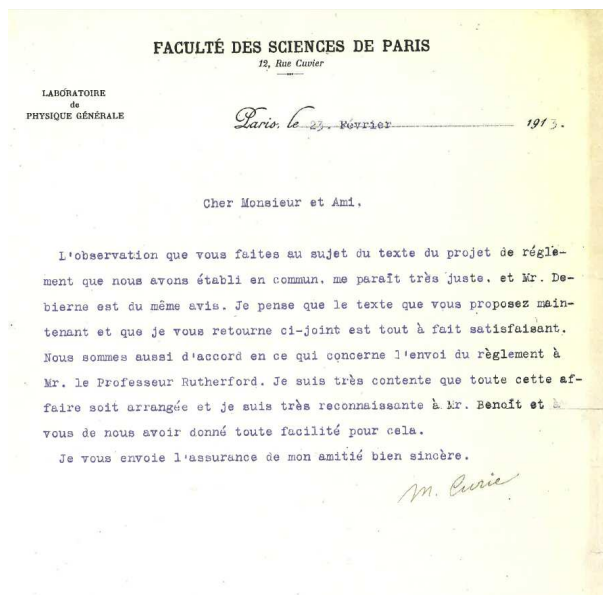


Fig. 6: Letter written by Marie Curie to Charles-Édouard Guillaume, thanking him for his contribution to the draft rules developed with him and confirming her approval for sending the final version to Ernest Rutherford, BIPM Archive.

Guillaume and not the Director of the BIPM signed the rules of procedure for the use of the international radium standard, including the practicalities of using the international standard; it is also Guillaume who sent the final version of the rules to Rutherford (Fig. 7) who agreed with the proposed amendments.

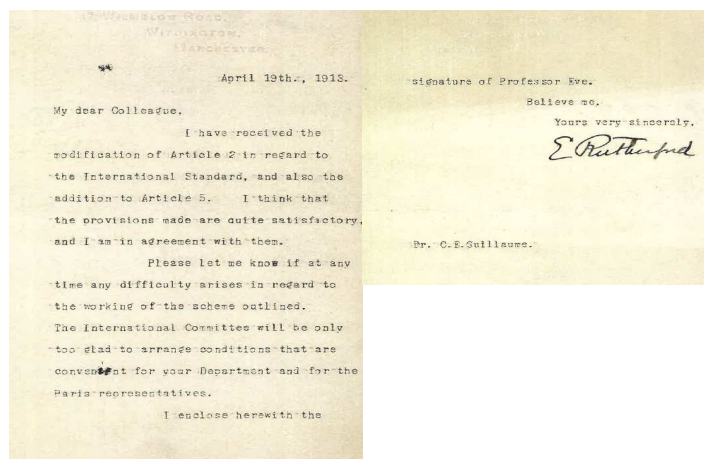


Fig. 7: Letter dated 19 April 1913 from Ernest Rutherford to Charles-Édouard Guillaume confirming the final approval of the rules by the members of the Commission.

5. An official and unofficial role for the BIPM

On 21 February 1913, the international radium standard was placed by Marie Curie, André Debierne and Charles-Édouard Guillaume in the first safe (Fig. 8) of the first floor of the basement of the Observatoire at the BIPM. It was kept in the same building as the international prototype of the kilogram and the metre but not at the same level for two reasons: it was possible to collect the standard immediately after having informed the BIPM and the safe was under the entire responsibility of the Director of the BIPM or his deputy who could have a permanent access to it, as explained by Benoît to Meyer:

Two depots for prototypes have been established at the International Bureau. The first is a deep vault, where the international prototypes, the Metre and the Kilogram and their witnesses are locked in a safe. This vault is closed by a double iron door with three security locks, one of the keys is in my hands, the second is in the Archives de France and the third is in the hands of the President of the CIPM. (...) The second deposit is also a vault, but not as deep as the previous one. It is there that we keep in an iron chest the standards which remain available for the work of the Bureau (...). This vault has an iron door with a single safety lock (...). I am the only one who has the key, and it is only I who carries out these operations. It is obviously in this repository that the radium standard should be placed. It should therefore be delivered (...) carefully packed, protected by sealed envelopes, preferably metallic, because the vault is frequently quite humid, and the wood, let alone the paper, can be altered more or less quickly. Once locked in the deposit, the standard would never be touched by anyone, and it would be kept there with the same guarantees as our own prototypes. However, it would be understood that in the event of misfortune (fire, robbery, theft), the Bureau would not assume any kind of liability whatsoever towards the Commission. (Letter of J.-René Benoît to Stefan Meyer, May 1912, Archive BIPM).



Fig. 8: The safe where was placed the International Radium Standard. ©BIPM

It is interesting to consider, as explained by A. Danjon⁶ that

« (...) From 1913 to 1940, the International Bureau of Weights and Measures was depositary of the international radium standard, but merely informally. »

(Report of the 1st meeting of the CCEMRI, 13 April 1959).

In the 1910s, the mission of the BIPM was to maintain the two fundamental units of the Metric System and was mainly directed toward the measurements needed for geodesy, the standardization of the metric system and the establishment of standards of length and mass. It could be considered as surprising, when taking into account the importance of radium internationally, that the depositary of the international radium standard did not appear in any official document of the BIPM or in the proceedings of the CIPM before 1952. The security concerns and, as explained above, the fact that to make it official it would have required a formal decision of the CIPM during one of its sessions and not simply through the approval of the President and Secretary of the CIPM are the main reasons. Guillaume was certainly happy to support Marie Curie in her work in offering her a place she found acceptable for the safekeeping of her radium standard.

The decision of the International Radium Commission to place the first international standard at the BIPM constituted in itself a full recognition at an early stage, of the status of international organization of the BIPM, which had existed for only 38 years. It was clear to the members of the Commission that the international radium standard had to be kept in a neutral and international place that was not affiliated with any State or laboratory. The BIPM had two other advantages: its seat was at a convenient distance from the Radium Institute in Paris, therefore it was easy to collect it to run the comparisons. In addition, it was under the responsibility of a close friend of Marie Curie, which was suitable for her.

While from the Radium Commission's side, the depositary of the international standard was very formal and accompanied by detailed rules for its use written in a procedure signed by all the members of the Commission, ironically, until 1959, the international radium standard officially did not exist at the BIPM. It appeared in none of the official reports and even the CIPM had to investigate in the 1950s to

understand how the first international radium standard had been kept during more than twenty years in the BIPM safe when the following question was raised:

« M. Volet raised the question of the deposit made as early as 1913 at the Pavillon de Breteuil, of an international radium standard, without being able to find, in the procès-verbaux of the CIPM, any mention of the conditions under which this deposit had been made. M. Danjon confirmed by reading a document (Journal de Physique, 1912, p. 823) that the deposit was made at the Pavillon de Breteuil by Mme Curie, in perfect agreement with Ch.-E. Guillaume. »
(Report of the CIPM, Meeting of October 1952)

The activities of the BIPM were extended: first to the standards for electricity and photometry for the standardization of measures and the determination of a temperature scale. The development of these new activities led to a revision of the Metre Convention in 1921. The extension of the activities of the BIPM to the field of ionizing radiation took place during a second stage.

6. Comparisons with the international standard

Marie Curie and André Debierne came to the BIPM for the first time to collect the international radium standard on 13 May 1913 for the determination of standard n° 3 of the National Physical Laboratory in the United Kingdom (Fig. 9).

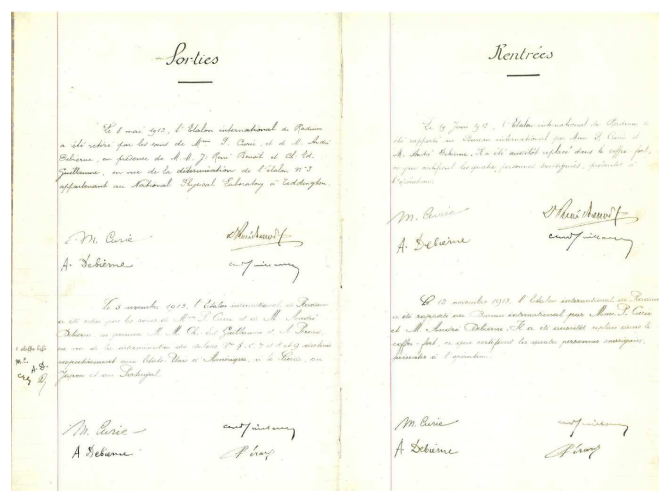


Fig. 9: First uses of the International Radium Standard reported in the Notebook kept at the BIPM. Archive BIPM

From 1913 to 1935, the international standard was taken out eight times for comparisons at the Curie Laboratory and was returned to the safe at the BIPM. With reference to the Notebook of the Radium standard, it is possible to follow the removal and returns to the safe of the international standard. Ten national radium standards were compared with the international standard at the Laboratoire Curie after having been compared with the secondary standard kept in Vienna, following the rules agreed by the Commission in March 1912. The certificates were established by the Laboratoire Curie (Fig. 10).

⁶ A. Danjon (1890-1967), President of the International Committee for Weights and Measures from 1954 to 1960.

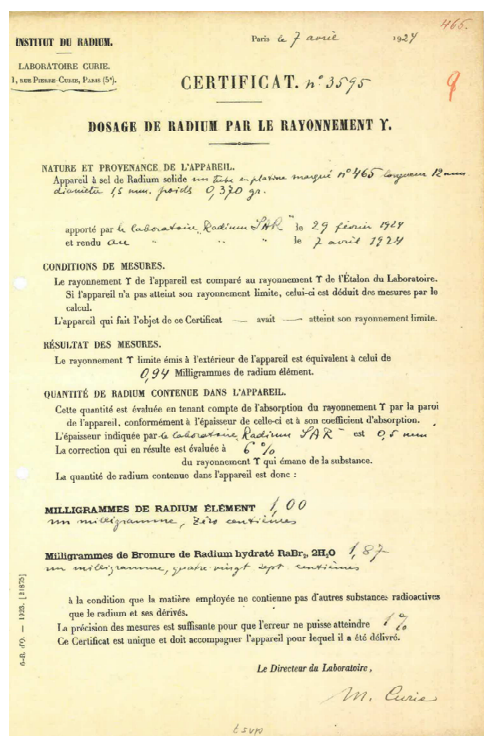


Fig. 10: A calibration certificate produced by Marie Curie in 1927, BIPM Archive.

Marie Curie was treated for a leukaemia and passed away on 24 July 1934 in Sancellemoz. In 1933, in front of the League of Nations, Marie Curie, during the debate on The Future of Culture⁷ that she was chairing, declared:

« I am among those who think that science has great beauty. A scientist in his laboratory is not only a technician; he is also a child placed before natural phenomena which impress him like a fairy tale. We should not allow it to be believed that all scientific progress can be reduced to mechanisms, machines, gears; even though such machinery has its own beauty. Neither do I believe that the spirit of adventure runs any risk of disappearing in our world. If I see anything vital around me, it is precisely that spirit of adventure, which seems indestructible and is akin to curiosity. »

The death of Marie Curie did not put an end to the history of radium. She anticipated her death and organized the handing over of her work to her daughter, Irène Joliot-Curie who was awarded the Nobel Prize in 1935 for her discovery of artificial radioactivity.

6. The new international radium standard

The same year as Marie Curie died, O. Hönigschmid performed a new determination of the atomic weight of radium using 3 g of radium and prepared twenty new radium standards that were made using pitchblende originating from Haut-Katanga in the former Belgian Congo and which were practically free of mesothorium.

Two of these standards, namely No. 5428 (containing 30.75 mg of RaCl_2) and No. 5430 (22.23 mg of radium chloride), were of equivalent mass to the Marie Curie standard. From 1935 to 1939, these two new standards were compared with the primary and secondary standards. Standard No. 5428 and No. 5430 were to replace those of Vienna (secondary standard) and Paris (Primary standard) respectively. The standard No. 5430 was attributed to France and given to the Laboratoire Curie (Chamié, 1940). On 21 April 1939, Frédéric and Irène Joliot-Curie transferred the new international standard to the BIPM.

Irène and Frédéric Joliot-Curie came to the BIPM on 30 May 1940 and with Albert Péard (1880-1960), then Director of the BIPM, collected the international standard to transfer it to a safe place (Fig. 11). Considering the threat posed by the war, the international standard was moved, for security reasons, as far as possible from Paris. The international standard was kept from 1940 to 1959 under the responsibility of the Institute of Radium of the University of Paris.

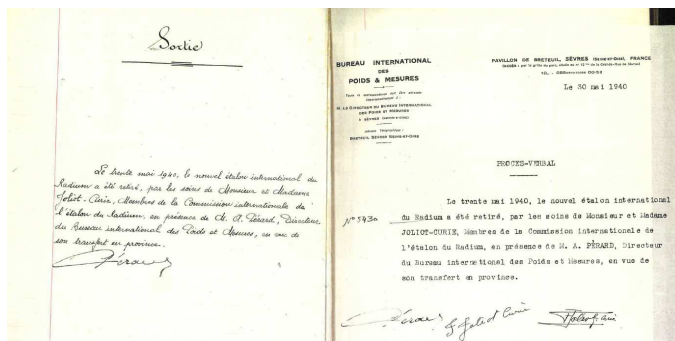


Fig. 11: The Second International Standard is taken off the BIPM on 30 May 1940, BIPM Archive

The international standard belonged to the International Radium-Standards Commission until 1951, when it was decided to transfer ownership to the new Joint Commission on Standards, Units and Constants of Radioactivity created by the International Council of Scientific Unions. It was further decided that the new standard should remain under the care of the BIPM and to take it out for comparisons at the Laboratoire Curie following a new procedure.

7. Extension of the activity of the BIPM to Ionizing Radiation

The extension of the activities of the BIPM to radionuclide metrology was requested at the 9th meeting of the General Conference on Weights and Measures in 1948 by the Soviet delegation:

To improve and to revive the activity of the International Committee and the International Bureau, the delegation of U.S.S.R. recommends to the International Committee to set up for the next session of the Committee a plan with practical measures, in particular :

...g) the organisation of comparison of national standards of radium and to maintain these at the Bureau international. (Proceedings of the 9th meeting of the CGPM)

In July 1953, the Joint Commission for Radioactivity (Commission mixte de radioactivité) at its meeting in Stockholm recommended to place the international radium standard No. 5430 for comparisons at the International Bureau of Weights and Measures. In the first stage, the Commission entrusted the International standard to the Radium Institute (Institut du Radium) in Paris.

In 1958, a discussion on the extension of the activities of the BIPM to the standards of radioactivity took place at the CIPM meeting following a consultation led by the International Commission on Radiological Units (ICRU) welcoming a proposal to charge the BIPM with organizing international comparisons of radioactive standards at the BIPM. The CIPM decided at this meeting to set up the Consultative Committee for the Standards of Measurement of Ionizing Radiation (CCEMRI). The CCEMRI was established to initiate a programme of work for the BIPM in the field of ionizing radiations and to make plans in terms of staffing and materials for its implementation. The aim was to enable the BIPM to run international comparisons of standards in order to coordinate global measurements for ionizing radiation.

The CCEMRI met for the first time on 13 April 1959 (Fig. 12). The first meeting of the committee was followed on 3 December 1959 by the

⁷ Madrid, 3 to 7 May 1933.

transfer of the radium standard to the BIPM.

While in 1913 the role of the BIPM was informal and limited to maintaining the international radium standard, as from 1958, the BIPM has been at the center of ionizing radiation activity, leading the coordination of measurement in the field of ionizing radiation metrology.



Fig. 12: Photo of the delegates of the first meeting of the CCEMRI, 15 April 1959, BIPM Archive

The conservation of the international radium standard at the BIPM was unanimously adopted with a resolution at the Eleventh meeting of the General Conference on Weights and Measures, held in Paris from 11 to 20 October 1960. It was also during this meeting of the CGPM that the name of the International System of Units (SI) was adopted. The CGPM adopted several resolutions: one was related to the international standard, authorizing the BIPM to officially keep the international standard, a second resolution (unanimously adopted with the exception of Belgium) opened the way toward the creation of the future BIPM Ionizing Radiation Section

« Resolution 4

The Eleventh meeting of the General Conference on Weights and Measures,

CONSIDERING the necessity to determine accurately some units and notions used in the field of ionizing radiations,

INVITES the International Committee for Weights and Measures to undertake without delay necessary studies,

REQUESTS the International Committee for Weights and Measures to undertake the necessary steps for decisions and actions which will be submitted to the twelfth meeting of General Conference on Weights and Measures. (Resolution 4 of the 11th CGPM, 1960)

Following the recommendations of the CCEMRI, the CIPM decided in 1961 to set up the Ionizing Radiation Section. The CGPM at its twelfth meeting in 1964 welcomed the creation of the new section with the adoption of Resolution 1 and an exceptional dotation.



Fig. 13: Start of the work to set up the ionizing radiation building BIPM Archive



Fig. 14: The building after the inauguration of the laboratories on 29 September 1964, BIPM Archive

In the meantime, the council of the University of Paris in a letter dated 9 March 1961, donated the standard No. 5430 to the BIPM and an international comparison of radium standards was organized in 1963. Later, primary measurement methods and the introduction of the SI definition for radionuclide activity with the becquerel replacing the curie, at the fifteenth meeting of the CGPM in 1975, replaced the need to hold such standards. In addition, it was not safe for the staff and the environment to maintain a radium salt of some strength sealed in a glass tube for an indefinite time because of the risk of the accumulated gas exerting a dangerous increase in pressure. The radium standard was safely removed from the safe on 26 February 1993 and given back later to the *Institut de Protection et de Sûreté Nucléaire* and placed at the CEA in Fontenay-aux-Roses which disposed of also other sealed radioactive sources owned by the BIPM.

The question of the heritage value of the standard was raised by Guy Ratel who wrote to Henri Sergolle, Director of IPEN, asking if he would keep the international standard considering its historical value.

The first international standard prepared by Marie Curie was the basis of the international measurement system for about 50 years – the original Key Comparison Reference Value (KCRV). In 2014, eighty years after Marie Curie passed away, Dr Martin Milton, Director of the BIPM decided to rename the building used by the Ionizing Radiation and Chemistry Departments in her honour.

8. Conclusion

Since it was established, the BIPM Ionizing Radiation Department has set up and maintains the international reference standards that are used in the BIPM key comparisons of activity and dosimetry measurements for the National Metrology Institutes. Ionizing radiations are present in many aspects of life today, including both radiations that occur naturally in the environment and artificially produced radiations. Ionizing radiation metrology today has a huge impact in healthcare: the direct impact of ionizing radiations on medical (diagnostics and therapy), environmental (natural and in emergencies) and nuclear industry activities, shows the need for a world-wide, harmonized system of quantities and units to assure the accuracy and comparability of their measurement.

« There is always the chance that a scientific discovery may become like the radium a benefit for humanity. » Marie Curie

Acknowledgements

Many sources of information are available regarding the history of Marie Curie and the International Radium Standard. This paper is mainly based on the Archives of the BIPM. André Allisy (1924-2017) with his paper published in *Metrologia* in 1994 wrote an interesting summary of the history of the Radium International Standard and documented the establishment of the Ionizing Radiation Section at the BIPM. Prof. Allisy worked at the BIPM from 1961 to 1989 as Director of the Ionizing Radiation Section, which he created. Prof. Allisy used his skill and good judgment to establish the four BIPM laboratories dedicated to: dosimetry measurements for x-rays and gamma-rays; neutron measurements; activity measurement for beta and gamma emitters; and determination of absolute alpha emitter energies. He surrounded himself with talented collaborators to rapidly build up the international reputation of the BIPM in these new areas.

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