Chapter 1
The Biography of a Trafficking Material

In 1904, an article titled "Radium and Radioactivity" appeared in *Century Magazine*, a monthly popular magazine published from 1881 to 1930. The article presents Marie Curie's personal account of the discovery of radium and radioactivity. In the article, Curie discusses in depth her arduous attempts to study the radiation of the compounds of uranium and that of known chemical elements, hoping to discover more which are endowed with atomic radioactivity. She revels that it was the chemists who supplied her with the materials she needed. "As I desired to make a very thorough investigation, I had resource to different chemists, who put at my disposal specimens—in some cases the only ones in existence—containing very rare elements." 1

Her next step was to examine different minerals, especially the oxide of uranium ore (pitchblende). To her great surprise, this specimen was found to be four times more active than oxide of uranium itself. The explanation was more than obvious. "The ore must contain a substance more radioactive than uranium and thorium, and this substance must necessarily be a chemical element as yet unknown."[1] Her attempts to isolate the new element would lead Marie and Pierre Curie, who joined her research shortly after, to the discovery of both polonium and radium, to the Nobel Prize in Physics in 1903, and to a second Nobel Prize in 1911, this time in chemistry. 2

This chapter attempts to present a cultural biography of radium. It is the biography of a material that, from the very first moment of its birth, became involved in the physical system of alpha, beta, and gamma rays and the atomic structure; in the chemical system of atomic weights, emanations, and transmutations; in the medical system of cancer treatments and radon spas; in the commercial system of luminous watches, women's cosmetics, and medical remedies; in the artistic system of luminous paintings and middle-class American culture; and in the industrial system of radium extractions, the production of luminous paint, and the beauty industry. 3

During the early twentieth century, radium evolved into a material of the everyday world as well as a "new research tool," in Pierre Curie's terms, of the laboratory site, bringing the above systems into close contact.[2] It traveled from laboratories to sites of medical practice and from educational amphitheaters to the physicists' 4 and chemists' workbenches as scientific objects often do. Yet it was also an item of commodification that was transferred from mines and sites of industrial production to those of consumption.

Anthropologists have long ago argued that in order to understand the concrete, 5
historical circulation of things one has to follow the things themselves "for their meanings are inscribed in their forms, their uses, their trajectories."[3] Besides understanding the circulation of the element that is called *radium*, I want to understand the culture that surrounded its circulation, the transformations in gender relationships that it motivated, the kind of exchanges that took place, and the forms of learned knowledge and gendered skills involved in the circulation of the material. Following around radium, one discovers what historians of science are less familiar with. In addition to being a scientific object with "wonderful and fabulous qualities,"[4] radium has been a highly valued commodity. In 1904, its price was $10–$15 per mg and just before the First World War, it escaladed to the astronomical price of $180.[5] Radium showed up as a consumer commodity in luminous watches; in women's lotions and creams; in toothpastes, cigarettes, and radium condoms; in ointments for medical use; and in food, drinks, clothing, and endless medical products. Its commodification involved complex political maneuverings, imperial commerce and colonial trade, efforts for monopolization, transformations of women's work, as well as rivalry between scientists and quack doctors over radium quantities, and the exchange of knowledge, skills, and radioactive materials among physicists, chemists, and medical practitioners.

To come to grips with radium's multiple identities as both a scientific object and a 6
commodity and to explore the paths of its circulation, I developed the concept of a *trafficking material*. These are materials, which travel from hand to hand, from discipline to discipline, from laboratory to laboratory, or from the scientific world to the world of commodification and consumption. Their main characteristic is their ability to take on multiple identities, not because they are shared between different worlds but because they are transferred across them.[6] Motion becomes the inseparable part of their identity which has never been fixed in the first place. Physicists and chemists needed more than a decade after radium's discovery to fully identify the new element, ascribe to and understand its properties, and describe and classify them.[7]

Used in scientific laboratories, trafficking materials shift focus from instruments 7
and experimental practices to material substances set on laboratory tables and manipulated by skilled experimenters who aim to reveal the "order of nature" in

the distinct cultural setting of the laboratory.[8] How do these materials arrive in the laboratory? Trafficking materials such as radium are traded, produced, prepared, and sold, and thus provide a glimpse of how the laboratory and its experimenters are connected to the rest of the mundane world. These materials, furthermore, provide a vital link between the laboratory and the warehouse, the hospital and the academic institution, between sites of production and those of consumption. They are the objects of overlapping networks of knowledge built by different actors. Becoming part of this network it is not only a matter of gaining scientific expertise but also of using the right strategy and of possessing the power to impose oneself. For instance, trafficking materials worked as Trojan horses for sustaining women's experimental work in the field of radioactivity in the early twentieth century. Being able to prepare radium sources for medical use, counsel radiologists about radium's curative properties or perform radium measurements on ocean sediments, women physicists and chemists were able to cross the boundaries of their discipline and move to the fields of medicine or oceanography.

Trafficking materials possess not only a scientific value but also a social, economic, and sometimes a patriotic one, as we will see in the case of the Viennese physicists of the early twentieth century. They are intimately connected with the knowledge of those who sell them and of those who buy them. They take many journeys and sojourns from production to consumption and scientific exploitation, and they have been used as instruments in order to obtain something else or to restrict and control the kinds of exchanges they are involved in. Moreover, trafficking materials function as devices for reproducing certain relations, often gendered ones, between people in the laboratory, in the work place, or in the market. Thus, trafficking materials are not merely objects but are essential signs in systems of signs such as those that we have already referred to in the case of radium. Mapping the geography of radium's use, a highly complex undertaking, leads to a gender system of laboratory work and is key in understanding how the lively system of science works. 8

The Radium of the Physicists

Radium was discovered in France at the end of the nineteenth century, but it was strongly linked to Röentgen's discovery of x-rays in his laboratory in Würzburg, Germany. In late 1895, Röntgen announced that the passage of an electric discharge from an induction coil through a partially evacuated glass tube produces what he called x-rays. The emitted radiation was able to penetrate not only the black paper Röntgen used in his original experiment but thick-material objects as 9 well. In January 1896, Henri Poincaré presented Röntgen's discovery to the French Academy of Sciences, posing the question whether any naturally fluorescent or phosphorescent substance could emit penetrating radiation similar to that of x-rays. To Antoine-Henri Becquerel's satisfaction, that proved to be possible in the case of uranium.[9]

The same year, Becquerel observed the darkening of a photographic plate in 10
contact with uranium crystals and described the invisible radiation emitted by uranium. In March 1896, during a meeting of the French Academy of Sciences, Becquerel presented his findings, which were then published within ten days. Shortly afterwards, based on intensive experimentation, he concluded that the emissions were not related to visible fluorescence but to a specific property of uranium.[10]

At the time, Marie Curie was working on her doctoral thesis under Becquerel's 11
supervision. She conducted her research on the rue Lhomond at the Ecole municipale de physique et de chimie industrielles (EPCI), in a damp storehouse turned into a physics laboratory. *Le hanger* (the shed), as the laboratory was known, was directed by her husband, Pierre Curie. Although modest and short of apparatus, the lab provided Marie with enough space to perform her experiments. After the discovery of the new radiation, Marie Curie decided to work on Becquerel rays or uranium rays as they were called at the time. Her aim was to investigate the properties of uranium radiation and a necessary first step was to develop an accurate and reliable method of measuring radiation. Pierre and his brother Paul-Jacques Curie, both prominent physicists working on piezoelectricity and physics of crystals, provided the necessary apparatus.[11]

A method based on photographic plates was unassailable for demonstrating the 12
existence of the new radiation but insufficient for measuring its intensity. The density of the exposure on the film, however, could be used as a crude measure of the intensity of the radiation, but it was not accurate enough. Curie aimed for something better. "Instead of making these bodies [the compounds of uranium] to act upon photographic plates, I preferred to determine the intensity of their radiation by measuring the conductivity of the air exposed to the action of rays."[12] The ionizing property of the radiation had already been used for the case of x-rays to measure their intensity. Despite their wide usage, instruments such as the gold leaf electroscope and the spinthariscope designed by William Crookes were not accurate and precise enough to be employed for the measurement of uranium rays. The need for new instrumentation became more pressing with the discovery

of the new radiation. Pierre and Paul-Jacques Curie had already devised an electrometer in the early 1880s based on the piezoelectric effect of quartz crystals. The apparatus measured small quantities of electricity in absolute terms.

In the light of the new and slowly emerging field of radiation physics, Marie employed the Curie electrometer in her research, equipped it with an ionization chamber, and transformed it into a reliable tool for ionization measurements. Carrying an electrometer from crystal to radiation physics, Marie demonstrated that the intensity of the radiation was proportional to the amount of uranium. The new method proved to be superior to the photographic plate method. As Marie conducted research on a number of other substances, she soon discovered that only thorium possessed properties similar to those of uranium. Her hypothesis was that radiation was an atomic property unrelated to its chemical structure. Additionally, pitchblende, raw ore containing uranium, was more radioactive than the amounts of included uranium could explain. Obviously, she concluded, there had to be a new radioactive element in the pitchblende. Her experiments with synthetic chalcolite supported her hypothesis and prompted Pierre Curie to involve himself fully in the study of radioactive substances. **13**

Both Marie and Pierre had approached the problem through physics and had been trained and integrated in that culture. Pierre worked on crystal physics and Marie had been working on the magnetic properties of various minerals under the supervision of the physicist Gabriel Lippmann.[13] Deeply devoted to research, Pierre concentrated on the study of the physical properties of the radiation while Marie performed the radiochemical analyses. Between the two, Marie crossed the boundary of her discipline by using methods from chemistry to analyze pitchblende samples while Pierre kept his identity as a physicist rigid. As Davis argues, "If he [Pierre] tended to concentrate on the physics aspect of the work of radioactivity and she on chemistry, this would seem to have been a matter of personal preference."[14] **14**

I argue that it was more than a simple preference. As Helena Pycior documents, Marie started to work on radioactivity in December 1897 and it was not before late March 1898 that Pierre joined her.[15] Forced by the subject of her research, by the time Pierre got involved, Marie had already integrated chemical methods in the study of the new substances. Her experiments with synthetic chalcolite, the study of all chemical compounds of uranium and thorium, and the testing of all known **15** chemical elements and certain minerals all occurred in this early period. Thus, the core of her own research program required her to continue working on the isolation of new elements.

In July 1898, after using a combination of electrometric methods and chemical analyses, the Curies discovered polonium. Since they were not members of the French Academy of Sciences, they were not allowed to present their results in the weekly meetings of the academicians. It was Becquerel who presented the discovery on their behalf on July 18.[16] 16

The emergence of the Curies' new research challenged the unity of traditional chemistry. French chemists and academicians soon became uncomfortable, feeling that they might lose control over their discipline. To chemists, outsiders like the Curies seemed to be encroaching on their resources and disrupting disciplinary boundaries. None of the first researchers was a chemist. Marie had primarily studied physics, receiving the Diplôme de licence ès sciences physiques (1893), and a year later, a *licence* in mathematics as well.[17] Pierre had received his *licence* in physics from the Sorbonne in 1877 and in the early 1880s, collaborating with his brother, discovered the phenomenon of piezoelectricity. At the time of their early research on radioactivity both were working in a physics laboratory, training engineers, and "recruiting students from the *écoles primaires supérieures.*"[18] Becquerel, who came from a family with a strong tradition in physics, attended the Ecole Polytechnique in 1873. Two years later, he was appointed as a demonstrator at the Polytechnique and then professor of physics in 1895. That year was significant for him because he was also appointed as a professor of physics at the Museum of Natural History, a position already held by two previous generations of Becquerels. In 1889, he was elected to the Academy of Science in recognition of his work in physics. [19] 17

The Chemistry of the Imponderable

It was probably because of Becquerel's membership in the Academy of Sciences that French chemists did not overreact. They simply insisted that before the new element could be given any official status, it had to be successfully isolated, its atomic weight had to be measured, and its spectroscopic characteristics analyzed.[20] The chemist Gustave Bémont, Pierre's close collaborator and director of the chemistry laboratory next door in EPCI, joined the team and the spectroscopist Eugéne Demarçay was also enlisted as a collaborator. Bémont offered his expertise on the tedious chemical analysis. In December 1898, 18 painstaking measurements and studies of the properties of radiation led the Curies to the discovery of a second element, the one they named *radium*. Becquerel was once again their representative in the academy. Shortly after, a joint publication by the Curies and Bémont appeared in *Comptes rendus*, announcing the discovery.[21]

It is no coincidence that the publication immediately following that one was Demarçay's "Sur le spectre d'une substance radioactive" (On the spectrum of a radioactive substance"), where he analyzed the spectrum of radium.[22] Marie coined the term *radioactivity* to name the research in radiation physics, rejecting the term *hyper-phosphorescence* used by J. J. Thomson in England as misleading for the nature of the new radiation.[23] 19

A Nobel Prize in Physics, awarded jointly to the Curies and Becquerel in 1903, affirmed the importance of the new emerging field. In his presentation speech, H. Törneblach, the president of the Royal Swedish Academy of Sciences, referring to the discovery of radium and the findings of Ernest Rutherford and William Ramsay on the release of helium by radium, admitted that they were "discoveries that are bound to be of great importance for the physicist and for the chemist alike."[24] 20

In the years that followed radium's discovery, there was a constant interchange of ideas, practices, techniques, and new knowledge between physicists and chemists. The contribution of the chemists proved to be essential in deciphering the mysteries of the new element. The French chemist André Debierne, the *chef de travaux* at Marie's laboratory after Pierre's death in 1906, suggested a number of chemical techniques and facilitated the work of physicists employed in the lab. Many young researchers flooded Curie's laboratory, working on the chemistry of the new science, while she was busy perfecting her methods of radium extraction and detecting new radioactive elements. From 1907 to 1914, 58 people worked at Curie's institute, most of them foreigners who came to learn at the source.[25] 21

In the Anglo-American scene, the situation was similar to the one in France. As Lawrence Badash describes, because some of the experiments required chemical separations of radioelements, the physicist Ernest Rutherford "secured the services of a young demonstrator in the chemistry department, named Frederick Soddy."[26] At the time, Rutherford was still at McGill University in Montreal, Canada, working on the nature of radium emanation. Harriet Brooks, Rutherford's first graduate student and one of the first women in the field, joined their research and in 1900, she successfully identified radium emanation as a radioactive gas 22 with lower atomic weight than radium. The following year, she moved to the Cavendish Laboratory in England to work with J. J. Thomson and later to Curie's institute where she conducted research with André Debierne as a *travailleur libre*.[27]

The traffic at Rutherford's laboratory, however, "was uncertain" as John Heilborn points out and "brought only a half of dozen people into the laboratory during Rutherford's tenure." Among them was a young German chemist, Otto Hahn, who arrived at McGill in 1905 after spending two years working with Sir William Ramsay in England and with an important discovery in his curriculum vitae. Hahn had identified a new radioelement that emitted thorium emanation and which he labeled *radiothorium*.[28] Meanwhile, Soddy had moved to the Chemical Institute of University College in London to join Ramsay's research. Only when Hahn returned to Berlin and was joined by the Austrian physicists Lise Meitner in 1907 did Germany start to be considered one of the most important radioactivity centers in the world. 23

The transfer of knowledge and its carriers—the physicists and chemists who conducted pioneering radium research—was taking place along with the transfer of the materials themselves. Before Rutherford moved to McGill, he was a fellow in the Cavendish Laboratory. A day or two before he left England in 1898, he ordered uranium and radium salts to be sent to his new address and he was also among the few lucky scientists to receive radium substances from Marie Curie as a gift.[29] Hahn also did not arrive in Montreal empty handed. With Ramsay's consent, Hahn had taken with him the radiothorium he separated from samples of barium chloride and the actinium that he and a collaborator had earlier proved to be identical to the new element that the German chemist Friedrich Giesel had named *emanium*. Hahn's radiothorium and actinium salts also followed him to Emil Fischer's laboratory in Berlin.[30] 24

Chemical work required large samples of scarce radium and thus materials mattered even more to the chemists than to the physicists. At the time, one of the most important suppliers for small quantities of radium was Friedrich Giesel, manager of the quinine production at the laboratories of the Braunschweig quinine factory Buchler & Co. Giesel used his chemical expertise for the extraction of radium from uranium ore and, starting in 1901, his factory became the first radium supplier. The Austrian Stefan Meyer, the Curies, and even Dmitrii Mendeleev in 25

Russia received their first samples from Giesel.[31] Rutherford was also able to order pure radium bromide from Giesel, taking advantage of a 300-dollar endowment offered by Sir Williams MacDonald, a significant patron of McGill University.[32]

Badash alone refers to an amazingly rich traffic of materials in 1913 when the concept of isotopy was at stake. The German chemist Kasimir Fajans sent his student Max Lembert from Karlsruhe to Harvard to work at the laboratory of the atomic weight expert Theodore Richards, an authority in the field. Soddy, who was also involved in research on isotopes, used Ramsay as the mediator to approach Richards as well. Lembert and Richards conducted control experiments on the atomic weight of ordinary lead to be compared with radioactive samples. The trafficking of radioactive samples was impressive. Fajans provided lead previously obtained from Giesel in Braunschweig; Richards got samples from Ellen Gleditsch, the Norwegian chemist who was then working with Boltwood; Ramsay sought supplies from the Cornwall pitchblende and the British Radium Corporation, a new company that established a factory for producing radium bromide under Ramsay's own directorship.[33] 26

Despite the fact that some chemists were eager to probe the mysteries of the new radioelements, the more traditional ones saw radioactivity not only as a physicists' intrusion into their field, but more importantly as an attack on the world view and the basic doctrines of their discipline. When in 1896, Mendeleev proposed the periodic table as a pedagogical way to systematize the existing chemical elements, his primary ordering was by atomic weight or, in his terms, the "elemental weights." Each element had a stable, fixed place in the system depending on its mass. Additionally, it was immutable without any possibility of becoming another element and had no substructure. Up to the end of the nineteenth century, Mendeleev's definition of an element prevailed in the chemical community. In his persuasive account of Mendeleev's work, Michael Gording argues that among the three phenomena that brought chemistry under attack, destabilized the entire discipline, and forced Mendeleev to defend his system was radioactivity.[34] 27

A key step that changed the notion of a chemical element and reshaped chemistry was taken in 1902. Studying the nature of radioactive emanations from thorium, Rutherford and Soddy came up with the theory of atomic disintegration. They concluded that a primary radioactive substance undergoes a series of atomic transmutations; that is: radioactive atoms give birth to a series of atoms of smaller and smaller weights, emitting alpha rays. Therefore, by losing the weight of an alpha particle, an atom would necessarily change species; in other words, 28