Introduction

This is a book about the materials and experimental practices of radioactivity research. It is neither an overview of the emergence of the field in the early twentieth century nor a collection of institutional histories of different research centers. It is also not an account of women's participation in a discipline that has been portrayed as one of the research areas most highly populated by women. Instead, the book is centered on radioactive materials, instruments, and gendered skills. 1

In this work, I employ a gender perspective in the study of experimental practices and laboratory materials. I seek to show how experimental cultures—ensembles of scientific practices employed by gendered subjects who share a certain material and epistemic style of research—in radioactivity are constructed and reshaped by scientists of different gender. At the same time, I explore the different ways experimental practices affect men and women in laboratory sciences and I broaden the notion of material culture by focusing specifically on materials that were both commodities and objects of scientific inquiry. I attempt to understand how purified radium ended up on laboratory benches, who completed the hands-on work of its extraction and isolation from tons of residues, who designed the experiments and instruments for probing radium's properties, and who carried radium outside of the physics laboratory to the clinics and medical amphitheaters. 2

I am interested in the circulation of radium, the making of connections, and the pursuit of power through strategies of partnership and collaboration. The redrawing of paths of exchanges brings us to a different millennium and moves us from scientific laboratories to hospitals, from academic sites to industrial sites; it connects different disciplines such as physics to medicine and chemistry; it reflects struggles for scientific preeminence and diverse partnerships between scientists and industrialists; it even reveals efforts for professional existence. 3

At the end of the nineteenth century, the discoveries of x-rays and radioactivity changed the meaning of physics by reshaping its boundaries and transforming its material culture. New apparatus such as scintillation counters and photographic emulsions were developed in order to detect individual particles. Physicists were now able to replace previous macroscopic experiments with finer-grained experiments that were sensitive to such microscopic phenomena as interactions between individual particles. The shift in experimental techniques and instrumentation contributed to a new, dynamic interrelation of physics with other 4 disciplines such as chemistry and medicine. In fact, physicists, chemists, industrialists, instrument makers, and medical technicians claimed radium for their own fields and traded, bargained, bought, and sold it.

The flow of radium as commodity—medical, chemical, or otherwise—in the early twentieth century had very diverse and important implications for both individuals and institutions. In all cases, it functioned as a device for reproducing relations and linking producers, distributors, consumers, and users. However, commodities represent very complex forms of knowledge, for example, the knowledge that goes into the production of the commodity and that which goes into appropriately using it. In the case of radium, I want to know who had the skills to prepare radium sources, brush the mixture of alcohol and zinc sulfide from the small rectangular glasses used for scintillation counting, read the photographic plates of emulsions, set up apparatus for experimental work, analyze radium samples, define radium doses for medical use, and perform experiments. 5

But what did it mean to do experiments? To answer this question, I explore the laborious laboratory processes and the culture that surrounded them. I study the ways instruments were designed and modified, and how materials were obtained and prepared. This book is an attempt to convey a sense of what it meant for the participants—both men and women—to be engaged in experimental practices in early radioactivity research. At the same time, keeping in mind that laboratories are gendered spaces, I show how the use of materials and instruments reveal the ways gendering of experimental skills took place. 6

An Epistemological and Historiographical Shift on Materials

As Jeff Hughes has recently argued, from the 1940s to the 1980s, the historiography of radioactivity and nuclear physics had been dominated by canonical accounts that either stressed the theoretical developments and significant discoveries in the field or produced hagiographies of the important figures along with reminiscences and uncritical popular history. Even the historiography of women in radioactivity research has followed the same trend. From Marie Curie's to Lise Meitner's biographies, the main concern has been to provoke scientific and public fascination and appreciation for those women connected to radioactivity. Only during the 1990s did historians begin to rethink the history of the field in terms of the experimental practices and material culture that established and defined it as such.[1] Recent studies have been centered on 7 instruments, scientific objects, conceptual tools, disciplinary networks, and experimental skills, following a general trend in science studies which shifted focus among other issues to scientific objects.

As early as 1989, Susan Leigh Star and James Griesemer coined the term "boundary object" in order to capture the entanglement of heterogeneity and cooperation in scientific practice. Focusing on the early history of a natural museum, Star and Griesemer analyzed the ways in which amateurs, professionals, trappers, and administrators involved in the museum made sense of their different viewpoints. Objects of their common interest, such as fossils, species, and subspecies of mammals and birds, field notes, and maps inhabit multiple worlds, simultaneously satisfying the informational requirements of each of them.[2] 8

In 1997, reading the history of the synthesis of proteins in the test tube from material traces, Hans-Jörg Rheinberger introduced the notion of "epistemic things" —things that embody concepts. In contrast to those historians of science who have dealt with disembodied ideas, Rheinberger emphasizes physical structures, chemical reactions, and biological functions, in general, material entities or processes that take place in the laboratory. His history is, he argued, "a biography of things, a filiation of objects, not as pictures of an exhibition, but as records of the process of their coming into existence."[3] 9

In 2000, Lorraine Daston compiled *Biographies of Scientific Objects*, which presented the histories of several scientific objects from ether to dreams, from mortality tables and blood pressure to cytoplasmic particles. The book is about the ways scientific objects are born, forming contingent creations out of local cultural and material resources. Four years later, "things," and this time *Things That Talk*, gave life to another collected volume of essays, which "knit together matter and meaning."[4] The book spans a wide spectrum of "things"—from soap bubbles to paper clippings to glass flowers—and is concerned both with the ways "things" are made and with what "things" actually are. 10

In the last 15 years, for historians of physics and chemistry, writing the biographies of their objects of inquiry has meant writing about instruments and laboratory technologies.[5] In the life sciences, objects such as manometers, tissue slices, or even living organisms such as *Drosophila*, have been analyzed as part of the material culture of the laboratory.[6] It is only recently that materials have also attracted the attention of historians of science and acquired epistemological value. In "A Science Whose Business Is Bursting," Simon Schaffer explores the paths 11 through which a commonplace commercial entity, such as soap bubbles, turned into a representative "thing" in nineteenth-century physics. To Schaffer, "the ephemeral bubble" becomes a vital link between the warehouse and the cabinet, giving the historian the chance to have a glimpse of both worlds.

In a different venue, Ursula Klein and Wolfgang Lefèvre have extended these lines of investigation by shifting their focus from instruments to material objects and from institutions and experimental activities to sites of intersection in the arts and crafts. They depict eighteenth-century chemistry as a science of materials and trace their shifting ontologies over the span of a century. They argue that "Eighteenth century chemists treated materials as useful commodities, perceptible objects of nature, and entities carrying imperceptible features." Such a perspective challenges traditional and powerful views of Lavoisier's role in chemical revolution. 12

"Seen from our new perspective," Klein and Lefèvre explain, "Lavoisier and his collaborators reaped the rewards of a century. In so doing, they introduced reforms of concepts, theories, analytical methods, classificatory structure and language. Yet, they did not initiate an ontological rupture. Chemists continued to live in largely the same world of objects before and after the Lavoisierian reforms." In the *Making of Materials,* a collected volume, Klein touches once again upon the importance of the materiality of things and the intersection of science, technology, and society. The material objects under inquiry were all materials applied in the everyday world as commodities and at the same time were objects of scientific inquiry. Thus the central view on the history of experimentation is replaced by a de-centered approach that takes into account forms of making and knowing in early modern natural history.[7] 13

Writing the Biographies of Materials

Anthropological and cultural studies have focused on the social life of commodities as they are the material objects that unite archaeology with cultural, social, and economic anthropology, art, and economic history.[8] Borrowing an anthropological view, science studies scholars have argued that "things" have cultural biographies since they are not only produced materially but are also culturally marked as being a certain kind of thing. "In doing the biography of a thing," as the anthropologist Igor Kopytoff puts it, "one would ask questions similar to those one asks about people: What, sociologically, are the biographical possibilities inherent in its 'status' and in the period and culture, and how are these possibilities realized? Where does the thing come from and who made it? How does the thing's 14 use change with its age, and what happens to it when it reaches the end of its usefulness?"[9] What could it mean then to write the history of radioactivity as a biography of radium and radioactive materials, commodities which link the laboratory to the mundane world?

In ways familiar to the anthropology of material culture, what is significant about the adoption of radium as a commodity is not the fact that it was adopted but the way it was culturally redefined and put to use. Its biography reveals a wealth of cultural data depending on the path of its exchanges: the way it was acquired; the institutions that host it; how and from whom the money was assembled to pay for it; the identity of both those who produced it and those who consumed it; the ways it was manufactured, advertised, and sold; the owner's relation to those who produced and promoted it; the networks developed for its promotion; and the signs embodied in its use. Radium's biography is complicated by the many social lives it lived in an unsettled geography. From France to Austria and from Austria to the United States, from the mines to the chemical laboratory to the hospital or the corporation's sales catalogue, radium has been in constant traffic. Throughout its several lives, it has been endowed with meaning and became a sign in a system of signs. In Roland Barthes's terms, radium was transformed to a myth—maybe the most powerful one in the early twentieth century—that is, a system of communication, a mode of signification.[10] 15

Let us take an example. In 1921, two grams of radium went on display in Grand Central Palace in New York City. This is an immense amount considering that the production of one gram requires 500 tons of carnotite ore, 500 tons of chemicals, 10,000 tons of distilled water, and the energy of 1,000 tons of coal. The exhibit was organized by Radium Chemical Company, which first produced luminous paint for watch dials and instruments and then moved to the manufacturing of radium-containing needles and other sealed devices (largely for cancer therapy) for lease or sale to hospitals and research laboratories. Obviously, the event targeted physicians and nurses. The exhibit also included daily demonstrations of the penetration of gamma rays of radium through a three-quarter inch vanadium steel cylinder. Motion pictures and photographs in display made the audience familiar with the complex process of radium's extraction, purification, and refinery. Every night, the radium was transferred under high police protection to the house of the chemist Hamilton Foley, who was responsible for the exhibit.[11] 16

In this exhibit, radium clearly held powerful meanings constituted by the myths of science, medicine, industry, commerce, and state power. The public lined up to witness the accomplishments of scientific authorities and the miracle of the new element. What made it a miraculous material were its properties: its rays penetrated opaque objects, radium needles cured cancer, it was used in paint to decorate everyday life, and its ore needed tedious work to be transformed to the material in display. Faced with these several myths, the visitor needed to identify himself as a consumer, a potential buyer of the Radium Chemical Company's products. 17

In an attempt to unravel its different myths, radium and the experimental practices that it defined are kept at the front and center of the chapters that follow. These chapters tell the part of radium's life story that relates to the Institute for Radium Research in Vienna, and to certain gender relations in the work place. Moreover, the metropolitan setting of Vienna, a center of an empire in transition, reveals the ways in which the material was interwoven in an international scientific network and caught up in major political upheavals. 18

The Scene of My Historical Play

In 1910, a Viennese lawyer and industrialist combined resources with the Austrian Academy of Sciences and the state to establish the Institut für Radiumforschung (Institute for Radium Research) in Vienna. The institute specialized in investigating chemical and physical aspects of radioactivity and was devoted exclusively to research. Franz Exner, a prominent member of the Viennese bourgeoisie and the Austrian Academy of Sciences, became its formal director. However, his student, Stefan Meyer, a young and talented physicist, handled the supervision, planning, and administration of the institute from the beginning. 19

By the end of the 1910s, the physicists of the Vienna Institute were already considered leading figures in the European community of radioactivity research. Serious competitors were located in only three other research centers: Marie Curie's institute in Paris, Ernest Rutherford's laboratory in Manchester, and the Laboratorium Hahn-Meitner at the Kaiser Wilhelm Institute for Chemistry in Berlin. The Vienna Institute provides an ideal setting for studying both radium and the experimental culture of radioactivity. 20

On the one hand, the Viennese had access to the rich resources of uranium pitchblende of the St. Joachimsthal mines in Bohemia at their disposal and were able to acquire radium in sufficient quantities for experimental work. They even entered the small network of physicists doing research on radioactivity as the main providers of the pricey material to scientific laboratories and soon became known for their prominence in radium research. 21

From its inception, the institute had a very strong staff, including many women—an extremely unusual fact for the time. Leading figures such as Ludwig Boltzmann, Victor von Lang, and Exner had helped women assimilate themselves into Vienna's academic community and welcomed them into their physics laboratories. After their first admission to the University of Vienna in 1897, the number of female students increased substantially, rising from 37 in 1897–8 to 796 in 1913–14. During the same period, about 30 percent of those who were enrolled in the philosophical faculty chose the field of physics. 22

The Radium Institute was able to attract large numbers of those educated women and integrate them into the local and international scientific community. Especially during the 1920s, more than one-third of the institute's personnel were women. Most importantly, they were not just technicians or invisible assistants; they were independent researchers who handled radium sources for their own experiments, designed their instruments, and participated in the international scientific community. 23

To analyze such an exceptional institutional setting, I will focus both inside and outside the laboratory and show that these boundaries are never fixed. At the turn of the twentieth century, Vienna was an extraordinary cultural setting where the city's intelligentsia produced distinct "schools" of thought in architecture, music, painting, philosophy, and psychology. In this creative milieu, a surprisingly dense network of academic institutes and medical facilities developed on the margins of the Ringstrasse, the impressive boulevard that surrounded the old city of Vienna. Enmeshed socially and culturally in the life of the city, an area known as the Mediziner-Viertel grew out of the needs of natural scientists and physicians and was also shaped by the liberal ideology and feminists' petitions for women's acceptance into university studies, Vienna's world of intellectuals and artists, and the Kaffeehaus culture. For instance, in the area's coffee shops, female students 24 associated with their male colleagues and exchanged ideas. Indeed, it was at this time that Viennese coffeehouses served as centers of social and epistemic interactions.

As recent studies have suggested, however, the city should be considered not merely as a location where science occurs but also as a setting that has affected the evolution of science, its methods, instrumentation, concepts, and objects of research.[12] The case of the Radium Institute reveals several aspects of such an interrelation between science and the city. The symbiosis of medical institutes with those of chemistry and physics within the Viertel provided the Viennese community of radioactivity researchers with a unique opportunity. For example, a network of scientists conducting research on the application of a variety of radioactive materials was expanding rapidly in the neighboring medical and biological institutions. On several occasions, radium was prepared at the Radium Institute and delivered to the Radium Station of the Allgemeines Krankenhaus (General Hospital) to be used in cancer therapy. The interdisciplinary nature of the field and the trade of radium offered scientists exceptional opportunities for crossing disciplinary boundaries. In Vienna, this proved to be a successful strategy for women to gain access to radioactivity research and sustain their role as active experimenters. 25

In addition, the fact that the Social Democratic Party gained control of the government of the city in 1919 and retained it for the following 15 years proved to be of crucial importance. A socialist program of municipal reforms was soon designed to transform the social, cultural, educational, and economic infrastructure of the capital. One of the targeted issues was gender politics, which was significantly altered by the policies and discourse of the Social Democrats. As historians of the period suggest, it is not surprising then that from 1919 to 1933, the enrollment of women at the University of Vienna increased steadily. 26

The unique constellation of progressive politics and supportive, politically aware personalities created the local conditions that enabled women to play a major role in the Radium Institute as well. The fact that the institute was a piece of Vienna's political history became more obvious during the 1930s. When the fascists seized power in Vienna in 1933, they deliberately put an end to most of the progressive forces of Viennese society. Especially after the *Anschluss* and the German Nazi occupation in 1938, Social Democrats, feminists, and Jews, including those of the Radium Institute, became the targets of a hate campaign and totalitarian politics. 27

How did women's everyday dynamic presence in laboratory life affect men's 28
perception of their own research practices? A central argument of this book is that gender actively and constructively shaped experimental cultures in radioactivity and was not merely an external factor in laboratory life. To support this claim, the focus shifts to the study of a controversy, a favored methodological tool in the sociology of experimentation.[13]

The methodological advantage of examining controversy is twofold. First, it allows 29
the comparison of experimental practices in diverse institutional settings, particularly when laboratories that share the same epistemic goals differ in their material cultures. By studying such differences, the historian can gain an understanding of how experimental cultures are shaped and how they affect the production of scientific knowledge. Second, instances of scientific controversies can reveal the roles that gender plays in an ongoing conflict. How, for example, are experimental skills gendered in different settings, and how are the material cultures of the laboratories transformed when more women are actively involved in experimentation? What role do materials play in the sustainability of research and research positions?

The controversy examined in this book took place during the 1920s between the 30
Vienna Institute and Ernest Rutherford's research laboratory at Cambridge University. Although the starting point of the quarrel concerned discrepancies over the artificial disintegration of light elements, it gradually developed into a fierce battle over the reliability of instruments and techniques, Rutherford's credibility in the field, and the accuracy of various theories and experimental results.[14] Rutherford's group, all male and mainly young students of physics, used the affluent resources of Cambridge and tied their research to the reliability of the scintillation counter, an instrument deployed for counting tiny flashes of light produced on a zinc sulfide screen by the impact of charged particles. In contrast, the Vienna group, under the leadership of the Swedish physicist Hans Pettersson attracted a young generation of researchers—many women among them—who drew from the scarce sources of the institute and succeeded in gaining support of Swedish patrons and the International Education Board.

Among other things, the controversy accounted for the transformation of the 31
material culture of the institute. Tabletop technologies such as x-ray photographic films, scintillation counters, photographic plates of emulsions, all tabletop, portable, and cheap apparatus that were easy to design and use were closely tied to the experimenters' everyday lives. Interestingly, the instruments tell us the

stories of their designers and users. For instance, the transfer of the scintillation counter from the laboratory benches of Rutherford's group to the Vienna Institute is about politics of collaboration between the physicists in each group, gender assumptions concerning the instrument's use, and strategies of retaining authority in the field. In each setting, definitions of experimental tasks as skilled and unskilled were constructed based on different gender relations.

In the late 1920s, the Viennese shifted parts of the scintillation counter from one laboratory bench to another in order to save a technique that by all accounts was dying. Instead, the group at the Cavendish Laboratory was introducing the novel methods of wave mechanics to nuclear problems, altering their instrumentation and theoretical approaches. While the loyalty of the Viennese experimentalists to their material culture reveals some of their insecurity in the field, changes in Rutherford's group point to the importance of funding and resources in scientific practice. In the end, for the Viennese to lose their epistemic authority was less important than to lose funding and be "gently" excluded from the scientific community through the private resolution of the controversy. 32

In this book, sociological attention is centered on how the controversy was resolved and on how differently women and men responded to the rearrangements of their laboratory. Nonetheless, to tell the history of technology transfer and to focus on scintillation counters and zinc sulfide screens is also to explore the epistemology of the experiment. For instance, by sustaining the material culture of their institute, women were also maintaining the gender assumptions of their group, of who had the right to perform experiments, prepare materials, and design instruments. After the Anschluss, some of the institute's women were forced to become part of large scientific groups where access to the instruments was hierarchically prescribed. They lost control over their experiments and had to abandon their patterns of research and alter their work relations in the laboratory. How did this affect their actual research? Part of the answer lies in the shift from scintillation screens to photographic plates, photoelectric cells, and finally photomultipliers in the 1940s. It also involves the shift from radium to radioisotopes, from an expensive commodity manipulated on a laboratory bench by tabletop apparatus to a product cheaply and easily manufactured by big machines. The details of the above history will be covered throughout the following chapters. 33

In chapter 1, I sketch the biography of radium as a trafficking material—a material which is traded and bargained as both a commodity of the mundane world and as a scientific object—the building block of the field of radioactivity in the early twentieth century. It was the vital material around which research communities and, in the long run, a whole discipline became organized. 34

Chapter 2 introduces the reader to the main scene of my story—the Institute for Radium Research in Vienna—and follows the physicists' attempts to organize their research in one of the most technologically advanced institutes of their time. It is there that radium and the experimental practices that this book explores were centered. In this chapter, I pay attention to the ways the architecture of a science building shapes and is shaped by gender relations in experimentation. 35

Chapter 3 explores the interrelation of the science of radioactivity to the city of Vienna, emphasizing the role of the urban setting of scientific institutions to women's participation in research. In both chapters 2 and 3, radium is shown to be a trafficking material that defined individual and institutional partnerships, the urban construction and architectural design of science buildings, and the exchanges of knowledge, instruments, and expertise. 36

Chapter 4 moves on to the 1920s and concentrates on the role of politics to the construction of the institute's gender profile, while chapter 5 concentrates on the controversy that developed between the Cambridge and Vienna experimenters. The key player in this controversy was the scintillation counter, an instrument that was transferred from one laboratory to the other, exemplifying gender differences in experimental practices. 37

The topic of chapter 6 is the aftermath of the controversy, examined at two closely intertwined levels: the scientific and the political. In the backbone of the narrative is the fact that dealing with a trafficking material, the women of the institute, after losing financial support, were driven to transform the borders of their discipline. The fascist seizure of power in 1933 and the new political and social order the Nazis imposed during the late 1930s, deeply affected life at the institute. After the Anschluss, Jewish men and women were forced into exile, underlying the fact that gender and racial discrimination were entwined. With an emphasis on those women who played a crucial role at the institute, I follow their life and work trajectories into the early 1940s. 38

In the last chapter, I sketch the story of Marietta Blau's eventful immigration to the United States and her equally eventful consideration for a Nobel prize in 1950. Her constant struggle to survive in the new world of high energy physics provides some hints about how and why women shifted from being active experimenters to industrial designers and laboratory support staff in the 1940s and 1950s. Having lost the advantage of manipulating a trafficking material—mostly useless in the 1950s world of easily produced radioactive isotopes—and forced to function in a different experimental culture than the one in Vienna, Blau found herself working as industrial designer and far from innovative research. 39

A Note on Sources

Historians are expected to rely on archives as the primary depositories of facts and decisive historical sources. As the historian of science Helge Kragh defines it, "a source is an objectively given material item from the past created by human beings."[15] Going through a list of the most important sources, Kragh includes letters, notebooks, manuscripts, scientific papers, and diaries. In the research for this book, I went through published scientific papers, letters, notebooks of finances and revenues, manuscripts, the annual bulletin of the Institute for Radium Research, as well as the almanac of the Austrian Academy of Sciences. Trips to several archives scattered throughout Europe, the United States, and Mexico gave me the opportunity to follow the trajectories of some of the protagonists of this story and reconstruct their laboratory life. Oral history and interviews filled some of the gaps about which the archival material was silent. Unless otherwise noted, translations of the above materials are my own. 40

Despite the fact that these common historical sources are absolutely necessary, they are not sufficient to grasp the complexity of laboratory life. I therefore additionally looked at photographs, not just as illustrations of a historical period, but also as evidence of the politics of collaboration within the institute, as proofs of material exchanges, and as indications of radium consumption and commodification. The photographs drawn from the online Oak Ridge Associated Universities' Health Physics Historical Instrumentation Museum Collection, an amazing source of radium instruments, radioactive quack cures, and medical products particularly illustrate the wide use of radium as commodity. Laboratory photographs either from the Central Library for Physics in Vienna or Agnes Rodhe's and Artur Svansson's personal archives also give a hint of how everyday life was structured at the Radium Institute. 41

I also used blueprints as a valuable source for historical analysis, as they express, contain, and portray gender discourse. The science studies scholar who is willing to pose questions of how gender politics and human relations define, and are defined by, spatial arrangements can find answers in the inner architecture of the laboratory and its spatial positioning in the city. Further, the map of the city provides a glimpse of existing scientific and commercial networks, of intellectual and material exchanges, and of political and academic alliances. I argue that the ways scientific buildings are arranged, interconnected, designed, and function define the ways practitioners alter, diversify, and rework the structure of their laboratory life. 42

Notes

Note 1: Hughes, "Radioactivity and Nuclear Physics" (2003).

Note 2: Star and Griesemer, "Institutional Ecology" (1989).

Note 3: Rheinberger, *Toward a History of Epistemic Things* (1997), 4.

Note 4: Daston, *Biographies of Scientific Objects* (2000); Daston, *Things That Talk: Object Lessons from Art and Science* (2004), 10.

Note 5: The literature has grown vastly. See for example Galison, *Image and Logic* (1997); Holmes and Levere, *Instrument and Experimentation in the History of Chemistry* (2000); Lenoir, "Instrument Makers and Discipline Builders" (1997).

Note 6: See for example Clarke and Fujimura, *The Right Tools for the Job: At Work in Twentieth-Century Life Sciences* (1992); Kohler, *Lords of the Fly: Drosophila Genetics and the Experimental Life* (1994).

Note 7: Klein and Lefevre, *Materials in Eighteenth-Century Science*: *A Historical Ontology* (2007); Klein, "Shifting Ontologies, Changing Classifications: Plant Materials from 1700 to 1830" (2005); Klein, *The Making of Materials* (1500–1800) (forthcoming).

Note 8: Appadurai, "Introduction: Commodities and the Politics of Value" (1986). Anthropological studies of material culture rest on the differences between gift and exchange and concern the ways objects come to convey and condense value and cultural meanings, fashion selves, and construct identities. As Nicholas Thomas argues, "Objects are not what they are made to be but what they have become." Thomas, *Entangled Objects* (1990). See also Myers, *The Empire of Things* (1991); Thomas, *The Commodity Culture of Victorian England* (1990). Gender studies have added one more dimension to the material culture that of the ways things are gendered. See for example Martinez and Ames, The *Material Culture of Gender, the Gender of Material Culture* (1997); de Grazia and Furlough, *The Sex of Things* (1996); Kirkham, *The Gendered Object* (1996).

Note 9: Kopytoff, "The Cultural Biography of Things: Commoditization as Process" (1986). See also Lamberg-Karlovsky, "The Biography of an Object: The Intellectual Style Vessels of the Third Millennium B.C." (1993).

Note 10: Barthes, "Myth Today" (1973).

Note 11: "$500,000 Radium is Exhibited Here," *New York Times*, November 14, 1921, 9:2(3).

Note 12: Galison and Thomson (eds.), *The Architecture of Science* (1999); Dierig, Lachmund, and Mendelsohn (eds.), *Science and the City* (2003).

Note 13: See, for example, Shapin and Schaffer, *Leviathan and the Air-Pump* (1985); Pinch and Bijker, "The Social Construction of Facts and Artifacts" (1987). Controversies have been discussed from a philosophical point of view in Machamer, Pera, and Baltas, *Scientific Controversies: Philosophical and Historical Perspectives* (2000). See also Nelkin, *Controversy: Politics of Technical Decisions* (1992).

Note 14: Experiments on artificial disintegration involved the transmutation of one element to another by bombardment of alpha particles and the emission of long-range particles.

Note 15: Kragh, *Introduction to Historiography of Science* (1987), 120.

