Review Essay

ELEMENTS, PRINCIPLES AND THE NARRATIVE OF AFFINITY

Mi Gyung Kim: *Affinity that Illusive Dream: A Genealogy of the Chemical Revolution*, Cambridge, MA: MIT Press, 2003.

ABSTRACT. In the 18th century, the concept of 'affinity', 'principle' and 'element' dominated chemical discourse, both inside and outside the laboratory. Although much work has been done on these terms and the methodological commitments which guided their usage, most studies over the past two centuries have concentrated on their application as relevant to Lavoisier's oxygen theory and the new nomenclature. Kim's *affinity* challenges this historiographical trajectory by looking at several French chemists in the light of their private thoughts, public disputations and communal networks. In doing so, she tells a complex story which points to the methodological and practical importance of industrial and medical chemistry. The following review highlights the advantages and snares of such an approach and makes a few historiographical points along the way.

1. HISTORIOGRAPHICAL OVERVIEW

For many of today's historians of science, reading a book about early modern chemistry would most probably induce a heinous case of intellectual dyspepsia. Perhaps this can be attributed to the gastronomic overtones of funny sounding words like 'butter of arsenic', 'milk of lime' and 'tartar of wine'. Or, perhaps 'Plessy's green' and 'Plimmer's salt' make for a bad side salad in classes where the main course is really Newton, Darwin or social discourse. These esoteric names serve to make the subject unpalatable to scholars unversed in the seemingly anarchical and archaic vocabulary of 'chymistry' as it existed in the centuries between the scientific and chemical revolutions.

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One way many historians have reacted to this situation is by framing their work in relation to its relevance to concepts which are at least familiar to the modern reader. Since the 19th century, this approach has produced a number of elegantly written books in which the time between the careers of Robert Boyle and Antoine Lavoisier is retrospectively filtered through the so called 'Chemical Revolution'. Though helpful in translating the work of Enlightenment 'chymistry' into the language of modern science, these studies ignore the vast experimental culture of chemistry as practiced in medicine, industry and provincial societies. Thus, when an intrepid researcher seeks to step outside the chemical revolution historiography, there are relatively few sources available which offer guidance on how to untangle the research programmes, nomenclature and ontologies which guided pre-Lavoisierian chemistry.

Nevertheless, over the past few decades a rising number of studies have addressed the laboratory practices and epistemological commitments of early modern chemists. Building on the studies of Hélène Metzger, Reijer Hooykaas and Maurice Crosland,[1] the 1970s and 1980s witnessed the work of Frederic Lawrence Holmes, Allen Debus, Arthur L. Donovan, Karl Hufbauer, Norma E. Emerton and David R. Oldroyd.[2] Holmes continued to write on the subject throughout his career, producing two of the most helpful texts on early modern France: *Eighteenth-Century as an Investigative Enterprise* (1991) and *Antoine-Lavoisier–The Next Crucial Year* (1999). The foundation laid by these authors has paved the way for more nuanced studies that have investigated issues more relevant to the actual practice of early modern chemistry. A role call of these studies would include: Marco Beretta's excavation of the history of chemical classification and nomenclature;[3] Bernadette Bensaude-Vincent and Jan Golinski's work on chemical communities;[4] William R. Newman and Lawrence M. Principe's explication of the influential role played by alchemical methods and imagery in the Scientific Revolution;[5] and, finally, Andreas-Holger Maehle and Brian Nance's emphasis on the central role played by therapeutics and experimental pharmacology.[6] Key to many of these studies, especially those that focus on the 18th century, is the concept of chemical affinity. In particular, Alistair Duncan's work addressed the subject from a pan-European perspective and Ursula Klein focused in on Etienne-François Geoffroy's affinity table and workshop traditions.[7]

Mi Gyung Kim's *Affinity that Illusive Dream* follows in the wake of these studies. Like the work of Maehle, Donovan and Bensaude-Vincent–as well as other 18th century intellectual historians like Anders Lundgren, Roy Porter and Mikulás Teich[8]–Kim concentrates on a specific linguistic and national context. Instead of analytically presenting an argument, she gives a Foulcaultian narrative with characters drawn primarily from the *Jardin du roi* (f. 1635) and the *Académie royale des Sciences* (f. 1666). The stage is mainly Paris, with a few scenes set in provincial societies. Spanning the period between the 17th and the 19th centuries, the plot is the complex history of chemical affinity. In telling this story, two terms continually emerge as part of the intellectual scenery: 'element' and 'principle'. She defines these two in a manner followed by many historians of early modern chemistry. The word *principle* was used by the Paracelsian tradition to represent the three basic forms of matter (the *tria prima*): salt, sulphur and mercury. Some of the chemists of this school held that these principles were really secondary manifestations of a hitherto unidentified universal form of matter. The word *element* was taken from the four material divisions offered by Aristotle: air, fire, water and earth. By the 17th century, these elements had been redefined in response to laboratory experimentation. Overall, in the face of the innumerable vocabularies used by early modern chemists, pure manifestations of these two ontologies were nearly impossible to find. But as a historiographical tool (and a piece of the scenery of course), Kim has followed the lead of past historians in agreeing that 'Paracelsian Principles' and 'Aristotelian Elements' are the most helpful typologies available at present.

2. THE LEMERYS, HOMBERG AND GEOFFROY

Rather than concentrate on one single person, chapter 1 is dominated by a 'troop' whose work would later be relevant to the affinity tables proposed by Etienne-François Geoffroy in 1718. From the start, Kim emphasizes that each of these chemists conflated (either synonymically or metonymically) the use of 'principle' and 'element' when seeking to talk about matter in its most reducible form. As shown throughout the rest of the book, this was also the case for most chemists who lived before 1800. Paying close attention to the different definitions of 'principle' and 'element' associated with the variegated analytic methods and chemical communities of the *Jardin* and the *Académie*, Kim concentrates on Samuel Cottereau Du Clos (1598–1685), Claude Bourdelin (1621–1699) and Nicholas Lemery (1645–1715). Building on the careers of these chemists, the main character that she treats in chapter 2 is Wilhelm Homberg (1652–1715). For the most part, the setting is the *Académie* after it was restructured in 1699. Homberg held that the fire of the sun (which he also called the 'matter of light') was a universal solvent that could reduce chemical principles into their 'ultimate corpuscles' (the former term being inspired by Descartes, not Newton). Based on this theory, Homberg used a burning glass to see whether principles could be reduced to even more basic forms of matter. In the end, he concluded that such a reduction was not possible and that, practically speaking, there were five principles of matter: sulphur, salt, mercury, water and earth. Additionally, drawing from his experiments on acids (which he held to be a type of salt), he suggested that mixts formed from principles were held together by a 'force' that seemed to be stronger in some substances and weaker in others.

The protagonists of chapter 3 are Louis Lemery (1677–1743) and Etienne-François Geoffroy (1672–1731). Son of the *Académie* chemist Nicolas Lemery, Louis, like many in the early modern chemists, held that fire was an aerial fluid. Assisted by his belief in corpuscularism and Homburg's burning glass, he suggested that fire was a universal solvent that gained its potency from 'matter of light' particles which used mechanical *force* (in a Cartesian sense) to break down substances. As a fluid, he argued that fire superceded distillation and solution-based techniques because it was such a powerful solvent. Likewise, he criticized the ontological status given to principles and called for experiments which sought to break them down into even more basic corpuscles. Yet this philosophically appealing programme was riddled with practical problems, the most pressing being the sheer impossibility of empirically quantifying the corpuscles that formed the base of his theory. Kim shows that it was exactly this issue which led Geoffroy, Lemery's older contemporary, to present a chemical *Table des Rapports* (Table of Affinities) in 1718. Rather than being interested in unquantifiable corpuscles, Geoffroy was content to take the principles of fire, water, earth, salt and metal at face value. In opposition to the emphasis that Lemery placed on fire (a fluid), Geoffrey advocated humid analysis, i.e. experiments which used solvents made out of aqueous solutions. This attracted criticism on several fronts, especially by those interested in 'phlogiston', the 'sulphur' principle and/or 'matter of light'. Geoffroy responded to these challenges by arguing that all of these were manifestations of inflammability– an act which allowed future generations of French chemists to regard phlogiston, sulphur and matter of light as different representations of an overarching inflammable principle.

3. ROULLE AND MACQUER

The influence Lemery and Geoffroy remained strong during the 1720s and 1730s. However, their ideas were both challenged and augmented by the next generation of chemists. Kim explores the role of principles and affinity from the 1740s to the 1760s by casting Guillaume-François Rouelle (1703–1770) and Pierre-Joseph Macquer (1718–1784) as her main characters. Although some of the more theoretical parts of Rouelle's writings suggest that he associated 'elements' with the basic molecules of matter and 'principles' with primary combinations of elements, in the end he took an instrumental (Kim prefers to use the word 'operational') approach in the laboratory and treated the principles of fire, earth, water and air as basic units of composition. In doing this, his approach to fire built on Georg Ernst Stahl's concept of phlogiston (which had started to circulate in France during 1720s) and Geoffroy's affinity table. The predominant methods Rouelle used to isolate these principles were fermentation and putrefaction. Interestingly, these methods were eschewed by Macquer, who was Rouelle's younger contemporary. Macquer's work harkened back to Homberg and Lemery's belief that fire was the most powerful chemical solvent. Yet, despite this difference, Macquer continued Rouelle's principle/element conflation and gave an operational priority to air, fire, earth and water in the laboratory. Macquer accepted these distinctions more readily because he was more concerned with developing a classification system for the affinities which were enshrined in Geoffroy's table. To this goal, he initially proposed two forms of affinity during the 1750s: simple and complicated. It was this move that led him and others in France (like Antoine Baumé, 1728–1804) and abroad (Torbern Bergman, 1735–1784) to later suggest several different classes of affinity: compound, intermediate, decompositional, reciprocal, elective and double. Based on her previous work on Victorian chemistry, Kim suggests (quite plausibly) that it was these affinity schemes which would later form an intellectual bridge between the tables of 18th-century 'principles' and the ontology of 19th-century 'elements' and compounds.

The central character of chapter 5 is Guyton de Morveau (1737–1816). Kim pays particular attention to the chemical ideas developed during his Dijon years (1760s and 1770s), that is, before his conversion to the new nomenclature in 1787. Although he would later be known as one of France's preeminent chemists, he began his career in the province as a lawyer. During these earlier years, he held that phlogiston was a universal solvent, thereby continuing the strand of French chemistry that placed emphasis upon methods that used igneous analysis. He did not warm to the dual usage of 'principle' and 'element' and this led him to favour the latter when discussing what he held to be the four most basic material particles: earth, fire, air and water. From the start, Morveau's logical mindset made him quite interested in chemical reform. In 1769, this inspired him to propose a new arrangement of Geoffroy's table. Whilst pursuing this arrangement, his interest in affinity (and also phlogiston) continued to grow – especially as he became more immersed in laboratory experimentation. In fact, at one point he even entertained Buffon's premise that Newton's inverse square law could be used to quantify affinity relationships between different types of particles. Though this idea was difficult to pursue, it did lead to a striking conclusion. Combining Rouelle and Macquer's affinity classifications with Newton's mathematical approach to gravitation, the articles that he wrote for Diderot's *Encyclopédie* in 1773 averred that affinity was a substance which could be quantitatively measured. Furthermore, even though Morveau often has been associated with nomenclature reform, Kim points out that this recalibration of affinity would also go on to play an important role in the ensuing decades.

4. THE 'ARSENAL' GROUP

Chapter 6 visits an old hero of chemical historiography: Antoine Laurent Lavoisier (1743–1794). Kim's plot treats his 1770s chemical career and gives special emphasis to the way his knowledge of acidity contributed to the development of his oxygen theory of combustion. Since Lavoisier used Geoffrey's affinity table during this time, he followed in the footsteps of many mid-century chemists who employed both 'principle' and 'element' to describe material particles of earth, water, air and fire. This might perhaps sound quite normal until one realizes that he also used both 'principle' and 'element' to describe oxygen from the 1770s through the 1780s. Additionally, although Lavoisier's 1764 notes from M. de la Planche's lectures indicate that affinity was one of the 'most difficult' concepts to understand, he used the term to describe the tendency of oxygen (his name for the respirable 'common air' and Priestley's dephlogisticated air) to unite with certain bodies and not with others. Drawing from the previous century's interest in universal solvents (usually in their inflammable or aqueous form), Lavoisier proposed that oxygen was the real 'universal' agent of solvency. This move, though foreign to modern readers, was conceptually possible for him because many early modern chemists (including those interested in investigating the 'airs' of pneumatic chemistry) held that fire, water and air were *liquids*. More importantly, this context allowed him to reconfigure the mediums traditionally associated with chemical reactions. Instead of 'bathing' a compound with fire (combustion) or solutions (water and acids), Lavoisier turned to air. Once this had been done, oxygen and the isolation of airs became focus of his campaign to eliminate the hold that principles held over chemical nomenclature. But, as Kim points out, even though he did not agree with Geoffroy's conception of *rapport* nor his table, the idea of affinity as a potentially quantifiable entity played a notable role in his 1770s work.

As is well known in the history of science, French chemistry was profoundly reshaped by Lavoisier's oxygen theory during the 1780s. What is generally not emphasized is that he did not emphatically reject the early modern definition of the four elements until 1789 when he published *Traité élémentaire de chimie*. This pronouncement was inspired by his own experiments and the 'conversion' of Guyton, Antoine François Fourcroy (1755–1809) and Claude-Louise Berthollet (1748–1822) during the mid part of the decade. Kim collectively refers to these four chemists as the 'Arsenal Group' and chapter 7 shows how this fellowship used the concept of affinity in their work. Following his adolescent distaste for affinity, Lavoisier set out to criticize contemporary affinity tables in 1783. However, this ironically led him to suggest an additional column for oxygen. More importantly, like Mourveau's work of the previous decade, he became even more interested in finding a way to quantify affinities–a goal which mirrored his concurrent efforts to quantify heat (which had by then been renamed 'caloric'). Kim holds that it is this 1780s research which led Lavoisier to reverse his base opinion of affinity: 'Having mocked chemists' affinities and analogies in his youth, he had ironically come to appreciate the importance of chemical affinity. He sought to detail the affinity relations of oxygen as the basis of his new chemical system, supplemented by a quantitative measurement of affinities' (349). This appreciation for affinity also held for the work his Arsenal colleagues were conducting at the time. For example, before his oxygen conversion in 1786, Fourcroy's 1782 *Leçons élémentaires d'histoire naturelle et de chimie* offered several different classes of affinity.

Moreover, the research he made while writing this text brought him one step closer to Lavoisier's programme. He became convinced that elements and/or principles, as they were then defined, were empirically suspect and that chemists needed to focus on quantifying the affinities which guided chemical reactions. Like Fourcroy, Guyton's work during this time reflected a similar mindset.

The hero of *Affinity's* final chapter is Berthollet, the youngest member of the Arsenal Group. After the French Revolution, both he and Guyton went on to become two of the leading authorities on chemistry in France. Unlike Lavoisier, Berthollet had shown a notable interest in affinities during the earlier part of his career. With the oxygen theory and the new nomenclature firmly set in motion, his 1795 lectures indicate that he sought to bring chemistry more in line with physics by pursuing experiments which concentrated on how attraction and repulsion occurred between what he then held to be elements: oxygen, hydrogen, carbon, azote, sulphur, alkali and earth. As this classification indicates, 1790s chemical nomenclature was a fusion between the names developed in conjunction with the oxygen theory and those of the older elements and principles. Kim also shows that a close look at Berthollet's post 1800 work indicates that he maintained a strong interest in affinity up to the end of his career. Additionally, like Guyton, he sought to find a way to reclassify and quantify affinities (an interest which mirrored his desire to do the same for caloric). This led him to criticize previous conceptions of affinity and to offer a new system. Based on his belief that liquids (aerial and aqueous) were the ideal medium, he argued that affinity was the sum total of the attraction or repulsion exerted by solvents, cohesion, elasticity, efflorescence and gravitation. Once these forces were sorted out, he also held that the insolubility, elasticity and, possibly, caloric of an element or compound might also effect the outcome of a chemical reaction. Though visionary, these issues were generally too impractical for early 19th-century chemists – especially for those who wanted to apply their knowledge to medicine, industry or war. However, as Kim points out, the importance of the questions engendered by

Berthollet's interest in chemical affinity lies in the fact that he 'offered an important starting point for the later formulation of chemical dynamics in the 1860s' (425).

5. DEFINITIONS AND TERMINOLOGY

As my above comments indicate, this book covers many aspects of chemical affinity. Even though parts of it do fill a much needed gap in the history of chemical elements, principles and affinities, there are several qualities which detract from its clarity. One notable distraction is the arrangement of each chapter. It is here where Kim's Foucaultian narrative makes many sections seem as if they have no focus. More specifically, like many a Dickensian novel, they are far too long (sometimes sixty pages!) and most lack a noticeable introduction and/or conclusion. This lack of organization is unfortunate because it makes the relevance of minor characters and plot twists less than obvious. This combined with the book's lack of a glossary, especially for chemical terms, means that it will be a difficult read for someone who cannot readily spout off the early modern definition of 'volatile', 'fixed', 'lixivial', 'sublimate' or 'rarified'. Furthermore, though Chapters 1 and 2 address the history of key points that surface later in the book, much of their content is more deftly presented in Holmes' *Eighteenth-Century Chemistry*. In fact, despite foreshadowing ghosts (volatile spirits, if you will) of chemical Christmases yet to come, these two chapters are the weakest in the book and in the cost efficient tradition of Ebenezer Scrooge I recommend skipping them altogether if you are already vaguely familiar with early modern chemistry. In truth, these could have been easily reduced into one chapter meant to serve as a conceptual introduction to chapter 3's focus on Geoffroy. Relatedly, the presence of several nebulously defined historiographical terms and movements succeed in distracting the reader away from the plot. Let me elaborate.

Chapter 2 introduces the concept of *domain theory* (presumably a concept kidnapped from a branch of mathematical theory used in denotational semantics). Aside from giving no explicit indication in the main text of what this term actually means, it seems that Kim envisions 'domain' to be an intellectual community's predisposition towards a given topic. This being the case, she proceeds to offer three different 'domain' classes, each with its own representational calculus: (i) domain of nature (N): nature in its pristine form, e.g. unaffected by human analysis; (ii) domain of accomplished analysis (A): the data created in the chemical laboratory, i.e. artificial reductions of nature; (iii) domain of projected analysis (A'): 'the world of true principles' (or perhaps material particles) that really existed below the philosophically inelegant principles. Thankfully, these three terms only receive concentrated use in chapter 2, after which they fade away in the light of vocabulary taken directly from the authors under discussion. The 'domain' concept does surface a few more times, but the tripartite distinctions listed above are not used again. It seems that these terms are remains of an earlier article which should have been ironed out in the editorial process. This being the case, I could have simply passed them over without issue. But I have chosen to highlight them because they serve as a good example of a difficulty evinced to a minor degree throughout the book.

Kim's use of 'domain' points to a different and more implicit ambiguity in her presentation of the plot. A close look at her footnotes reveals that her earlier work was considerably guided by a wide variety of socially inclined historians influenced by the work of Jürgen Habermas and Andrew Pickering. In principle, this practice is not problematic–provided that the historiographical methods and/or terminology of these approaches do not overshadow the texts under analysis. However, the above 'domain' example from chapter 2 suggests that this is exactly what has happened. During the early modern period, most chemists, especially those practicing in the laboratory, realized that there was a difference in the types of data that they were using. This point is not a new one. Indeed, it was made several times in the studies on early modern chemistry mentioned at the beginning of this essay. Most of these attempt to use the terminology employed by the chemists that they were studying. From a purely pragmatic perspective, instead of complicating her narrative with terms which take a good deal of space to unpack and defend, it would seem that she could have made her task much easier by using early modern distinctions like ‘natural’, ‘artificial’ and ‘essential’ in lieu of her ‘domain’ terminology. The use of these terms has a long and fruitful history, both during the time of the early *Académie* and in later literature on the subject. Moreover, similar forms of unidentified and undefined ideological baggage surreptitiously appear throughout the work. Some examples are ‘cognitive authority’, ‘cognitive status’, ‘boundary behaviour’, ‘encoded’ and ‘contact zone’. Like her domain terminology, these detract from her narrative because she hardly offers any explanation of the underlying theoretical (both social and historiographical) assumptions that lie embedded in their definitions.

6. THEORY AND GENEALOGY

Aside from addressing the history of 18th-century chemistry in relation to affinity, a significant theme that runs throughout the narrative is the methodological predestination which afflicted most of the characters. Put more plainly, two different approaches to laboratory methodology appeared throughout the work. One focused on theoretical synthesis and the other on practical application. Theoretical approaches to chemistry saw laboratory experimentation as a venue for confirming ideas born out of rational reflection. Those of this ilk were fond of using Cartesian (and later Newtonian) mechanical language and imagery to discuss matter on a microscopic scale. Alternatively, practical chemistry, also called analytic chemistry, was more concerned with how the laboratory could be used in solving everyday problems. For chemists of this vein, the roster of their experiments was set in relation to practically orientated questions born out of problems arising in medical or industrial contexts. Naturally, these distinctions, like the idealized backdrop provided by Paracelsian principles and Aristotelian elements mentioned at the start of this review, only function as helpful guide. They are more like typological poles, between which each chemist can roughly be placed for the sake of expediting a clearer picture of early modern chemistry. This being the case, many studies which address this time form a cast of characters around a plot guided by theoretical chemistry. In many respects, this is probably the easiest way to approach a topic notorious for its linguistic inconstancies and ambiguities. However, this does not get us very close to seeing the type of chemistry that was practiced outside the academy. Aside from the new insight Kim gives regarding affinities, a great strength of this book is that it attempts to grapple with how practically orientated chemical questions were relevant to the academy. This is not an easy task and this explains why Kim sometimes chases some seemingly inane conceptual rabbits.

Ironically, this book uses actors in the academy to underscore the importance of chemists who lived in the province (and this is in spite of Kim's claim that Guyton was a provincial chemist). In many ways, this method only reconfirms the Chemical Revolution historiography that Kim wants to challenge. Readers of this work might find it a bit perplexing that her 'genealogy' skips over the numerous apothecaries, physicians, monks, dye makers, metallurgists, bleachers, merchants, etc., whose research was being filtered into the Parisian chemical community during the early modern period. Those interested in this topic will have to seek out more obscure studies based on manuscripts and texts that shed light on the practical nature of chemical experimentation.[9] To be sure, Kim does recognize the value of medicine and industry, but she offers little explication of non-academy institutions, like monasteries or guilds, which fostered chemical research. In fairness, these sources lie largely undisturbed in ecclesiastical and state collections across Europe–and France's archives are not as efficiently organized, networked or catalogued as those in Britain or Germany.[10] Yet the fact that Kim gestures towards the chemists contained in these collections is commendable and this predisposition hopefully points to a future project which explores how a topic like affinity was being applied in the French 'field'. Kim's book would no doubt provide a firm platform from which to launch such a study. But until then, we will still know little about the genealogy of the relatively nameless chemists, the silent majority, who practiced chemistry outside the academy.

NOTES

1. Hélène Metzger, *Les doctrines chimiques en France: du début du XVIIe à la fin du XVIIIe Siècle* (Paris: Les Presses Universitaires de France, 1923) and *Newton, Stahl, Boerhaave et la doctrine chimique* (Paris: F. Alcan, 1930). Reijer Hooykaas, 'The concepts of "individual" and "species" in chemistry', *Centaurus*, **5** (1958) 307–322; 'The discrimination between "natural" and "artificial" substances and the development of corpuscular theory', *Archives internationales d'histoire de sciences*, **4** (1948) 640–651. Maurice P. Crosland, *Historical Studies in the Language of Chemistry* (London: Heinemann, 1962).
2. Frederic L. Holmes, 'Analysis by fire and solvent extractions: The metamorphosis of a tradition', *Isis*, **62** (1971) 129–148. Allen Debus, *The Chemical Philosophy: Paracelsian Science and Medicine in the Sixteenth and Seventeenth Centuries, vols. I & II* (New York: Science History Publications, 1977). Arthur L. Donovan, *Philosophical Chemistry in the Scottish Enlightenment: the Doctrines and Discoveries of William Cullen and Joseph Black* (Edinburgh: Edinburgh University Press, 1975). Karl Hufbauer, *The Formation of the German Chemical Community 1720–1795* (Berkeley: University of California Press, 1982). Norma E. Emerton, *The Scientific Reinterpretation of Form* (Ithaca: Cornell University Press, 1984). David R. Oldroyd's articles from this time are now collected in *Sciences of the Earth: Studies in the History of Mineralogy and Geology* (Aldershot: Ashgate, 1998).
3. Marco Beretta, *The Enlightenment of Matter: The Definition of Chemistry from Agricola to Lavoisier* (Canton: Science History Publications, 1993).
4. Bernadette Bensaude-Vincent and Ferdinando Abbri (eds). *Lavoisier in European Context: Negotiating a New Language for Chemistry* (Canton, M: Science History Publications, 1995). Jan Golinski, *Science as Public Culture: Chemistry and Enlightenment in Britain, 1760–1820* (Cambridge: Cambridge University Press, 1992).
5. William R. Newman, *Gehennical Fire: the Lives of George Starkey, an American Alchemist in the Scientific Revolution* (Cambridge, M.: Harvard University Press, 1994). William R. Newman and Lawrence M. Principe, *Alchemy Tried in the Fire: Starkey, Boyle, and the Fate of Helmontian Chemistry* (Chicago: University of Chicago Press, 2002). Lawrence M. Principe, *The Aspiring Adept: Robert Boyle and his Alchemical Quest* (Princeton, NJ: Princeton University Press, 1998).
6. Andreas-Holger Maehle, *Drugs on Trial: Experimental Pharmacology and Therapeutic Innovation in the Eighteenth Century* (Amsterdam: Rodopi, 1999). Brian Nance, *Turquet de Mayerne as Baroque Physician: The art of Medical Portraiture* (Amsterdam: Rodopi, 2001).
7. Alistair Duncan, *Laws and Order in Eighteenth-century Chemistry* (Oxford: Clarendon Press, 1996). Ursula Klein, *Verbindung und Affinität: die*

Grundlegung der neuzeitlichen Chemie an der Wende vom 17. zum 18. Jahrhundert (Basel: Birkhäuser, 1994); 'E.F. Geoffroy's table of different "rapports" observed between different chemical substances: a reinterpretation', *Ambix*, **42** (1995) 79–100'; 'The chemical workshop tradition and the experimental practice: Discontinuities within continuities', *Science in Context,* **9** (1996) 251–287. Klein has also just recently investigated the crucial link between material culture and pharmacological experimentation in 'Experimental history and Herman Boerhaave's chemistry of plants', *Studies in the History and Philosophy of Biological and Biomedical Sciences*, **34** (2003) 533–567.

8. Anders Lundgren, 'The new chemistry in Sweden: the debate that wasn't', *Osiris*, **4** (1988 146–168; Roy Porter and Mikulás Teich, *The Enlightenment in National Context* (Cambridge: Cambridge University Press, 1981).
9. Two 'obscure' sources in this category which I have found rather informative are Rainer Schnabel's *Pharmazie in Wissenschaft und Praxis, Dargestellt an der Geschichte der Klosterapotheken Altbayerns vom Jahre 800 bis 1800* (München: H. Moos, 1965) and the archival possibilities mentioned in the works included in the bibliography of Wolfgang Hagen Hein's *Die Deutsche Apotheke: Bilder aus ihrer Geschichte* (Stuttgart: Apotheker-Verlag, 1967). Also, see Robert P. Multhauf, *The History of Chemical Technology: An Annotated Bibliography* (Garland: New York, 1984).
10. For archives relevant to the chemical practices used in British pharmacology, see Lesley Richmond, Julie Stevenson and Alison Turner (eds), *The Pharmaceutical Industry: A Guide to the Historical Records* (Aldershot: Ashgate, 2003). For Germany, see Christoph Schuemann, *Der Anteil Deutscher Apotheker and der Entwicklung der technischen Chemie zwischen 1750 und 1850* (Frankfurt: Peter Lang, 1997).

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