The Old Ashmolean Museum and Oxford’s Seventeenth-Century Chymical Community: A Material Culture Approach to Laboratory Experiments

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Towards the end of the seventeenth century, Oxford’s chymical community embarked on the most ambitious project for the advancement of human knowledge ever realised in England: the Ashmolean Museum. Founded in 1683, the institution was part of Oxford University and home to the first official chair of chymistry in the country, with practical teaching directed by Robert Plot in the basement laboratory. The documentary information at our disposal is scarce and Plot did not leave us detailed accounts of his laboratory work. However, a large assemblage of laboratory tools, ceramic crucibles, and distillation apparatus were recovered from the site where the laboratory once operated. They offer a material perspective on the experimental agenda of one of the most important chymical laboratories in early modern Europe. The scientific analysis of the vessels and residues within them indicate that the work focused on technological innovation in the fields of glassmaking, specialised pottery, and zinc metallurgy, and shows how the laboratory kept close contact with some renowned artisan-entrepreneurs of the time. We argue that material culture offers an informative perspective on chymical practice in and beyond Oxford. The results provide fresh insight into the Old Ashmolean Museum, an institution that grew out of the Baconian spirit of the seventeenth century, where doing chymistry meant working at the intersection of artisanal and scholarly worlds.

Keywords: Oxford, alchemy, early modern, glass, metallurgy
Introduction

Recent decades have witnessed a major redefinition in the history of early modern science, with a renewed understanding of chymistry\(^1\) as a much more diverse and complex phenomenon than traditionally assumed.\(^2\) Accordingly, several major works have addressed the many facets of early modern chymistry and the wide array of motivations fuelling it.\(^3\) This historiographic redefinition is based on the recognition that early modern science was a practical as well as a theoretical endeavour, that it was as much about making as it was about knowing, and crucially that these two dimensions were intimately connected.\(^4\) Consequently, science historians have, increasingly, been paying more attention to aspects of chymical practice and to the material dimension of science.\(^5\) Experimental re-enactments of historical recipes have offered new insight into the material and sensory experience of chymical

\(^1\) Throughout this paper we will use the term chymistry following the practice established by William Newman and Lawrence M. Principe. For a discussion around terminology see William Newman and Lawrence M. Principe, “Alchemy vs. chemistry: the etymological origins of a historiographic mistake,” *Early Science and Medicine* 3, no.1 (1998): 32-65.


activities, and several research projects now engage in such activities, opening up space for fruitful cooperation between historians and specialists of material culture.

Against this backdrop, archaeology can play a crucial role in this cross-disciplinary redefinition. It provides a different set of primary sources, namely the material remains of chymical contexts that span the chemical terrain from metallurgical and apothecary workshops to glasshouses and more scholarly-oriented laboratories. Fragments of laboratory equipment, raw materials, and reagents contain a wealth of information on the practical dimension of chymistry, and their scientific analysis can unlock relevant details related to different chymical procedures, allowing for a more balanced, material-conscious history of science. This article is based on one such archaeological case study, the Old Ashmolean laboratory in Oxford. The analytical results on pieces of apparatus and on the residues found within them, presented in detail elsewhere, offer invaluable information on aspects of chymical practice and their implications for our understanding of chymistry in early modern Oxford.

The Old Ashmolean Museum in seventeenth-century Oxford

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10 Detailed results of the analytical investigation carried out on the assemblage can be found in Umberto Veronesi, Thilo Rehren, and Marcos Martín-Torres, “The philosophers and the crucibles. New data on the 17th-18th century remains from the Old Ashmolean laboratory, Oxford,” Journal of Archaeological Science: Reports 35 (2021). The present article focuses on the contextualisation and on the discussion of the results.
When Robert Plot was appointed director of experiments and professor of chemistry (the first at an English university) within the newly established Ashmolean Museum in 1683, Oxford was one of the most important hubs for natural philosophy in Europe. The Museum came into being as an ambitious project aimed at promoting a scientific community, and in addition to the basement laboratory, or officina chimica, it included a collection of curiosities on the first floor and a lecture theatre on the ground floor. Plot was himself one of the most important exponents of Oxford’s philosophical circle, having collaborated with Robert Boyle and later having been one of the founders of the Oxford Philosophical Society. But unlike many of his fellow natural philosophers, Plot did not publish anything related to his chymical work and, as a result, details of the laboratory practice during his time at the Ashmolean are relatively unknown. Scant pieces of information come from some papers he wrote as well as from minute entries of the Oxford Philosophical Society and the Royal Society, where he was also a member. He seems to have had a variety of philosophical interests ranging from the chymical manufacture of medicines to the natural history of England. One detail that surfaces from the analysis of Plot’s work is his recurrent preoccupation with making a profit from his chymical activities. Indeed, Plot did not receive a formal salary from the university and had to rely on student fees and on the sale of chymical preparations and processes developed in his laboratory. A contemporary description of the laboratory, for instance, informs us that the laboratory stored “a large quantity of prepared chemicals which may be purchased for money.” Thus, the officina chimica provided Plot with state-of-the-art equipment and a workspace where he could pursue his own personal agenda, whether for the purpose of reinforcing his status as a learned natural historian and philosopher, teaching the next generation of chymists, or making a profit by selling what was produced.

The archaeological discoveries

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15 Robert Gunther, Early Science in Oxford (London: Dawsons of Pall Mall, 1925), vol. 3 (on 326).
In 1999, a major refurbishment project was carried out at Oxford’s Museum of the History of Science, which today very fittingly occupies what had once been the Ashmolean Museum building. Upon removing the limestone slabs used to cover the earth floor at the rear of the building, it was discovered that the whole area had been used as a dump for materials that could be associated with the early modern basement laboratory. Besides thousands of human and animal bones linked to the teaching of anatomy, excavators recovered a large number of ceramic vessels that were part of the equipment of the laboratory, mostly crucibles, but also fragments of distillation apparatus and of other containers connected to chymical activities (figure 1). Most objects show signs of exposure to heat and chemical corruption such as discolouration and partial melting of the surface or residue layers adhering to the vessels’ walls (figure 2).

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FIGURE 1: The laboratory equipment excavated from the rear of the History of Science Museum in 1999 (from Hull 2003: 7-8). A: Beaker type (n. 1-9) and round-bottomed smaller type (n. 10-18); B: Tall closed crucibles (n. 2-4) and triangular ones (n. 5-8) plus a bottle (n. 1), two flasks (n. 9-10) and a cucurbit (n. 11). C: Ceramic retorts (n. 1-2), fragment of a large triangular vessel (n. 3), fragment of a lid (n. 4) and fragment of a drug jar (n. 5).

The discovery of this assemblage provides the invaluable opportunity to place the reconstruction of the material culture of a high-profile early modern laboratory centre-stage,
and to create a chymical microhistory based upon it.\textsuperscript{17} The scientific analysis of the tools and associated residues tells us much about the substances used in the laboratory as well as the recipes and the operations carried out. Since it was first recovered, the assemblage has been the subject of three rounds of analyses. An initial general screening of the artefacts was performed shortly after the excavation in 1999 by Chris Salter using an x-ray fluorescence instrument. On this basis, he proposed three main areas of activity: one related to zinc and lead, another to glass and glazes, and finally one related to sulfur, which he interpreted as possibly connected with the production of fireworks.\textsuperscript{18} Some years later some four crucible samples were analysed, this time using a scanning electron microscope. This is a technique that allows one to obtain high-magnification images of a sample’s cross-section, thereby investigating its morphology. However, it also provides the means to undertake microchemical analyses, either of the bulk composition, or by targeting selected areas. The results, published in this journal, add more detail to Salter’s initial interpretation and call for more extensive and invasive analyses.\textsuperscript{19} Moreover, based on the kind of operations that could be reconstructed, it was noted that “the chemical residues and experiments identified through scientific analyses […] seem more consistent with the chymistry of the late seventeenth century,” thereby proposing a chronology close to the early days of the Museum.\textsuperscript{20} A historical record provides a potential chronological limit for the dating of the laboratory equipment. The account written by Zacharias Conrad von Uffenbach, a German traveller who visited the laboratory in 1710, claims that he found it in partial ruin with broken equipment scattered all over the place and the ground covered in dirt.\textsuperscript{21} Further in-depth analyses on a larger number of pieces were performed more recently, enriching our understanding of what kind of chymistry was practiced at the Old Ashmolean.\textsuperscript{22}

**The crucibles**


\[\textsuperscript{18}\text{ Chris Salter in Hull, “The excavation and analysis,” (on 11-13). During that round of analyses, small traces of mercury were detected in two fragments, but the latest round could not corroborate such finding.}\]

\[\textsuperscript{19}\text{ Martínón-Torres, “Inside Solomon’s House.”}\]

\[\textsuperscript{20}\text{ Martínón-Torres, “Inside Solomon’s House,” (on 26).}\]

\[\textsuperscript{21}\text{ Bennett et al, Solomon’s House in Oxford (on 21).}\]

\[\textsuperscript{22}\text{ The study was carried out as part of Veronesi’s PhD project and a more detailed presentation and technical discussion of the analytical results can be found in Veronesi et al, “New analyses.”}\]
Analytic results provide initial insight into the laboratory’s supply of specialised equipment. The fabric and chemical composition of the triangular crucibles, for instance, strongly resemble that of German crucibles made in the region of Hesse and famous, in early modern times, for being the most technically advanced laboratory tools in circulation. Their exceptional resistance to heat and chemical attack was due to the use of a specific type of clay very rich in aluminium oxide and low in alkalis (sodium, potassium, magnesium, and calcium), which promote melting. Moreover, the vessels were subjected to a high-temperature pre-firing cycle, which caused the ceramic to vitrify and strengthen further.23 The triangular crucibles from the Ashmolean laboratory were likely imported from these German manufacturers. However, the non-triangular crucibles and the remaining vessels, whose composition also still denotes exceptional refractory properties, were probably made in England. Where and by whom is still an open question, but one intriguing possibility is that of the potter and entrepreneur John Dwight of Christ Church, Oxford (fl. 1671–1698). Not long before the opening of the Museum, Dwight had established a manufactory of high-quality stoneware and imitation porcelain in Fulham, near London.24 He was an innovator and Robert Plot went to visit his establishment, reporting that Dwight “hath discovered also the mystery of the Hessian wares, and makes vessels for retaining the penetrating salts and spirits of the chymists, more serviceable than were ever made in England, or imported from Germany itself.”25 The analysis of some triangular crucibles from the site of John Dwight’s pottery in Fulham showed that Dwight’s “secret” was the addition of crushed glass to the fabric, obtaining vessels that resembled the Hessian ones in appearance but not in microstructure.26 Some crucibles very much resembling those found at the Ashmolean were also discovered at Fulham, but these have not been analysed, hence the possibility that


Dwight may have supplied the Ashmolean laboratory still awaits confirmation. In any case, the interest expressed by Plot does suggest that some exchange existed.

The residues: glass making and zinc metallurgy

The analysis of the residues adhering to the fragments confirms that chymical operations involving glass and zinc are by far the most prominent activities carried out at the officina chimica, where the Ashmolean chymists appear to be following an experimental approach with a wide array of ingredients, trying variants and testing different recipes. The crucible fragments with evidence of glass-related chymistry are a good example of these variations on a theme. Indeed, the scientific analysis of some of the glassy residues (figure 2, top) identifies them as lead crystal, a type of glass invented in England towards the end of the seventeenth century and made with white sand (or crushed flints), litharge (lead oxide), and saltpetre (potassium nitrate). But while the composition of the Ashmolean glasses reflect the use of these ingredients their proportions vary between samples, as different ratios of ingredients were being mixed rather than combined in a standard fashion. Another way of experimenting with the lead crystal recipe was by colouring it blue, as one of the residues show, most likely through the addition of cobalt oxide, often referred to as zafferan. The amount of cobalt oxide necessary to tinge the glass would have been so little that its presence falls below the detection limits of the scanning electron microscopy (SEM) and energy dispersive X-ray spectroscopy (EDS) employed here. However, other colourants would have required larger quantities and would have been detectable.

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27 Pictures can be found in Green, John Dwight's Fulham Pottery (on 96-97).
28 Bennett et al, Solomon's House in Oxford (on 31-32).
Further tests on glassmaking recipes included ways to make opaque white glass, a highly specialised craft mastered by Venetian glassmakers and present in recipe collections of the Renaissance.\(^31\) Even here we noticed substantial compositional differences between the samples investigated, as the chymists used different ingredients and tried more than one recipe. The first difference concerns the choice of alkali-rich flux employed, seemingly saltpetre (potassium-based) in two cases, and a sodium-based reagent in another case.\(^32\) More

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importantly, differences also occur in the nature of the opacifying agent added to the glass. The most common way of obtaining an opaque white glass in this period was by adding a powder made of calcined tin and lead to the molten glass. While the lead would transfer into the glass, insoluble particles of tin oxide would crystallise and give the glass the desired characteristics. 33 Two of the Ashmolean crucibles were employed for such purpose and under high magnification we can see the small clusters of tin oxide crystals (figure 2). However, a third crucible seemingly used for the same purpose shows evidence of an altogether different reagent, namely the antimony ore stibnite, which led to the formation of very different crystals in the glass. 34 This latter procedure is rather uncommon for the period, but not entirely unknown. In the commentary to Antonio Neri’s *L’Arte Vetraria* (1612), the translator Christopher Merrett (1614-1695) adds a recipe featuring the same ingredients tested here, which “affords a very white enamel and serves with other mixtures for various colours.” 35

Turning to another area of experimentation, many of the vessels analysed were found to bear traces of laboratory operations that involved zinc. Often, these take the form of a powdery white crust stuck to the inner or outer walls of crucibles, as in the case of the fragment shown on the top of figure 3, which belongs to a tall crucible with a closed profile. Upon cutting through the unevenly distributed white residue, a layer of shiny silvery metal was revealed (figure 3, top-right). This is pure zinc, while the crust surrounding it is composed of zinc oxides and sulphates developed from corrosion during burial. The presence of metallic zinc is especially intriguing since early modern European natural philosophers and metallurgists still considered this a rather puzzling substance, whose status as a metal was not yet established. Such generalised confusion is reflected in the many names zinc and its minerals received in textual sources. 36 This was largely due to zinc’s peculiar thermodynamic behaviour of extremely high volatility, making it easily lost in smoke when the ore is heated up during high-temperature smelting. 37 This would have impeded any chances of obtaining


34 Calcium antimonate is the most common opacifying agent found in classical antiquity. For a list of references on this technology see: Moretti and Hreglich, “Raw materials, recipes and procedures” (on 23).


metallic zinc using a traditional furnace or reaction vessel. Instead, a distillation process was necessary whereby the mineral was heated in a reducing environment and the zinc vapour got channelled towards a cooler area of the vessel where it condensed as metallic droplets and could be retrieved. Variants of this technology were known in China and in India, and from around the sixteenth century zinc ingots from the East began to reach Europe, attracting a great deal of curiosity among both metallurgists and natural philosophers.  

However, zinc distillation would not be fully integrated into European practice until William Campion of Bristol obtained a patent for the process in 1738. We may therefore imagine a situation in which the Ashmolean chymists tried to replicate a distillation process in which the zinc vapour stuck to the crucibles’ walls and some metallic zinc would form.

A few more vessels in the assemblage can be linked to zinc metallurgy, including pieces of distillation equipment. The fragment of a rounded cucurbit bottom is one such example. Here, a white, zinc-rich glassy layer is noticeable on the external surface (figure 3, bottom-right), with the peculiar location suggesting that the vessel could have been used as a lid for another vessel, such that zinc fumes coming from the vessel underneath interacted with the cucurbit ceramic to create the residue. The two ceramic retorts (figure 3, bottom-left) are also indicative of distillation activities and may therefore have been used in experiments involving zinc, although no significant zinc traces were detected in the analyses.

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40 Hull, 2003 (on 11).
FIGURE 3. Laboratory equipment with evidence of zinc metallurgy. **Top:** Fragment of internal wall of the a tall closed crucible showing the characteristic white crust (left) and small section through it revealing the layer of zinc metal (right). **Bottom:** Ceramic retort with a smooth slip covering its internal surface (left) and cucurbit bottom with thick white glassy layer indicating contact with zinc vapours from below (right) (photos by the authors).

**Artisans, philosophers, and entrepreneurs: Oxford’s chymical community**

The picture emerging from the analysis of the Ashmolean’s materials indicates a notable interest in technological innovation that between the second half of the seventeenth and the first half of the eighteenth centuries would play a major role in English industry. The discovery of lead crystal residues in some of the crucibles is one such example. The glass had only been patented a few years before the opening of the Museum and its development, recipe-wise, was still underway. With time, different ratios of the ingredients and a general increase in the lead oxide content became the answer to growing problems with corrosion that affected lead crystal more than other types of glass. The substantial compositional differences noticed in the lead crystal examples analysed here may reflect similar concerns in

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understanding, replicating, and potentially improving procedures that were not widely known at the time.

The invention of lead crystal came at the end of a period in which the increased economic value of glass as a luxury commodity, in combination with the wealth of new information available from Christopher Merrett’s translation of the Arte Vetraria, had made practical glassmaking a topic of interest in erudite circles. As a brand-new product, lead crystal was attracting the curiosity of the scholarly world, as demonstrated by the visits of Robert Plot and Robert Hooke to George Ravenscroft’s glasshouse, where the glass was first patented, and their reporting on ingredients and procedures.\(^\text{42}\) Clearly, the potential for financial profit, should a successful recipe for a stable glass be developed, must have been an important drive in Plot’s chymical work. The fragment of blue lead crystal found at the Ashmolean further clarifies this picture. The use of zaffera to tinge glass blue is the centre of a lengthy comment by Merrett in his observations,\(^\text{43}\) while Plot sends a sample of cobalt ore to the Royal Society’s repository igniting a long discussion among the members.\(^\text{44}\) Further evidence for the London-Oxford exchange on this matter is provided by a letter between the Royal Society and the Oxford Philosophical Society dated 15 July 1685, “Dr Slare\(^\text{45}\) made some experiments with ye true kobalt or mineral of which ye zaffer is made, discovering what is ye true zaffer, which neither Dr. Merret nor any writer has yet done, it being nothing but this mineral calcined […].”\(^\text{46}\) Crucibles with evidence of opaque white glass in them further indicate that processes to achieve coloured glass were an important part of the Ashmolean’s chymical agenda. Among the many experiments reported by Boyle in his work diaries, some involve the manufacture of white and variably coloured enamels following Antonio Neri’s recipes,\(^\text{47}\) which shows the natural philosopher’s familiarity with the topic of making glass, a profession he considered worthy “to be made English”.\(^\text{48}\)

Beyond glass, several findings connect Plot’s laboratory to the metallurgy of zinc around the time of William Champion’s 1738 patent for zinc distillation, although this was a

\(^\text{42}\) Plot, Natural History Oxfordshire (on 253); Henry W. Robinson and Walter Adams eds., The Diary of Robert Hooke, 1672-1680. Transcribed from the Original in the Possession of the Corporation of the City of London (Guildhall Library), with a foreword by Sir Frederick Gowland Hopkins (London: Wykeham Publications, 1968) (on 53).

\(^\text{43}\) Cable, The World’s Most Famous Book on Glassmaking (on 336-340).

\(^\text{44}\) The discussion regarding the nature, name, and origins of zaffera can be found in Birch, History of Royal Society vol.4 (on 179, 418-420).


\(^\text{47}\) See particularly Boyle’s work diaries 14-15.

technological tradition well-rooted in previous centuries. Champion’s innovation represented the apex of a long artisanal tradition characterised by the use of zinc and zinc compounds to make brass, pigments, and medicines. Although the nature and behaviour of this substance was not fully understood, several texts from classical antiquity, as well as texts from later periods, mentioned how metallic sublimates were sometimes retrieved from cracks in the furnaces where the zinc-rich vapour had condensed and small droplets of metal had formed. This is what the geographer Strabo (63BC—23AD) describes when he reports the information regarding a type of ore to be found in Anatolia which “yields droplets of false silver” when heated in the furnace.\(^{49}\) Centuries later, the metallurgist Georgius Agricola (1494—1555) discussed the same phenomenon in the German lead-silver mines near Goslar, calling the metal recovered \textit{conterfei}.\(^{50}\) In the mid-seventeenth century, Rudolf Glauber (1604-1670) referred to the same substance as \textit{calmei} and added that by mixing this to copper one obtained brass.\(^{51}\) As it happens, Glauber is a rather outspoken advocate of the need to better understand zinc because, as he put it, “a great quantity is yearly burnt up and lost” while “that ore might be melted with far greater profit, if they did not so burn up the zink and force it into fume.”\(^{52}\)

A better understanding of zinc through attempts at distilling it from its ore would have had a deep impact on both the copper industry, with better-quality brass, and natural philosophy, with the discovery of a new metal.\(^{53}\) Indeed, finding viable sources of zinc for alloying purposes had been one of the main ambitions of the first British settlers who in 1607 founded the Jamestown colony in Virginia.\(^{54}\) Once more, the experimental agenda of the Ashmolean laboratory is characterised by the constant overlapping of economic and philosophical concerns. Making coloured glasses and successfully distilling zinc were both ways of investigating the inner workings of nature while simultaneously testing valuable procedures and recipes in an ever-expanding market. The story of lead crystal is as much about industrial espionage, patents, and monopoly as it is about the desire to understand why the early products invariably ended up corroding very quickly. But working on lead crystal

\(^{49}\) Craddock and Eckstein, “Production of brass in antiquity by direct reduction” (on 218).
\(^{52}\) Packe, \textit{The works} (on 320).
\(^{53}\) Thilo Rehren and Marcos Martínón-Torres, “Naturam ars imitata.”
\(^{54}\) Umberto Veronesi, Thilo Rehren, Beverly Straube, and Marcos Martínón-Torres, “Testing the new world.”
was also very much about the quintessentially alchemical quest to imitate nature through art.\textsuperscript{55}

This material landscape and the microhistory emerging out of it offer a point of entry into seventeenth-century chymical activities and the community of people who participated in them. The crucibles tell us much about the many connections existing between high-profile figures such as Plot, Boyle, Hooke, and Merrett, the circle of natural philosophers of the Royal Society and of the Oxford Philosophical Society, and chymist-entrepreneurs who brought major technological innovation to the industry. All were aware of one another’s endeavours and thus their stories and chymical interests often overlapped, even though their backgrounds, aims, and desires may have varied quite considerably. In a Baconian fashion, the cooperation between artisans and philosophers would not only result in a deeper understanding of nature but also in a significant improvement of crafts. The chymical programme carried out at the Ashmolean laboratory shows such efforts at integrating more production-oriented approaches with curiosity-driven experiments.

\textbf{Conclusion}

In this paper we argue that materials represent an important arena for the historiographic narratives that explore the permeable boundaries between craft and natural philosophy in early modern Europe as well as the dynamism of chymistry.\textsuperscript{56} Robert Plot’s understanding that the activities carried out in his laboratory were a chance for profit played an important role in his decision to take the job at the Ashmolean Museum, making him a chymist whose experimental work was somewhere between philosophical enquiry and


\footnote{On the idea of a flow between the laboratory and the workshop see Martínó-Torres and Rehren, “Alchemy, chemistry and metallurgy in Renaissance Europe,” (on 14); William R. Newman, “Alchemy, assaying and experiment,” in Holmes and Levere, eds., \textit{Instruments and Experimentation} (on 35-54); Dupré, \textit{Laboratories of Art, Alchemy and Art Technology}; Nummedal, \textit{Alchemy and Authority}, chapter 6.}
financial profit. A similar position can be seen in the work of Robert Boyle, who claims, in true Baconian fashion, that “an insight into trades may improve the naturalist’s knowledge” while at the same time “the naturalist, as well by the skills thus obtain’d, as by other parts of his knowledge, may be enabled to improve trades.” This constant mixture and interplay of aims and desires mirrors the very spirit upon which the Old Ashmolean Museum was founded, a place where empirical chymistry served the purpose of exploring the material world while also producing useful things. Finally, in revealing the close proximity between the universe of craft and that of science, a materials-centred approach to the history of chymistry acts as a reminder that no sharp line can be drawn between the former and the latter, and that an important part of the story lies precisely at this intersection.

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57 On the idea of entrepreneurial alchemy see Nummedal, Alchemy and Authority; Smith, The business of alchemy. On these liminal figures see Ursula Klein, “Hybrid experts,” in The Structures of Practical Knowledge, ed. Valleriani (on 287-306).
58 From the fourth essay of the Usefulness of Natural Philosophy, see Hunter and Davis, Works vol.6 (on 467).
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