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Adam Lonicer's Kreuterbuch and 16th century distillation

An experimental approach to the study of Adam Lonicer and some of the technology applied by him and his contemporaries in the production of medicines

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Master thesis in history of chemistry

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Cover illustration: F. M. Kirkemo, from a leaf of (Lonicer, 1569) and photo by Nils Kristian Th. Eikeland, NTNU University Library

To Solvor,
for your infinite patience

and to Sigrid Johanna
for your wonderful smile

Acknowledgments

A long list of people have been of invaluable importance in the making of this thesis. Many people have contributed in many different ways, and my gratitude is immense.

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I was fortunate to be able to participate in the *9th International Conference for the History of Chemistry* in Uppsala, Sweden, and I would like to give thanks for all the wonderful discussions and feedback that I was given by many of the eminent scholars who participated at the conference. In particular I would like to mention Lawrence Principe, Hjalmar Fors, Pierre Laszlo, Marco Beretta, Ernst Homburg, Annette Lykknes and Apostolos Gerontas who all shared invaluable insights and encouragement. The latter two not only at the conference, but also at NTNU. Annette was the one who first awoke my interest in history of chemistry, and Apostolos has on innumerable occasions cemented it.

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Finally I would like to thank my family, who has supported me through all the hard work and all my frustrations. My parents, who have encouraged me and supported me, and most of all my wonderful wife, Solvor who has been a world of patience, kindness, comfort, faith, support and love. None of this would have been even remotely possible without you.

My final thanks goes to my two year old daughter, Sigrid Johanna. The day is so much brighter when it is adorned with your smile and laughter.

Fredrik Motland Kirkemo
Stavanger, 15 November, 2013

Sammendrag

Kreuterbuch, publisert i 1569 av Adam Lonicer (1528 – 1586) ble svært populær i sin samtid. Dette er en rikt illustrert urtebok, hvor destillasjon er et sentralt tema. Boka har dannet bakteppe til en full-skala rekonstruksjon av destillasjonsprosesser fra 1500-tallet.

Med hjelp fra spesialiserte håndverkere fra universitetets verksteder ble det rekonstruert en ovn, utstyr samt det glassutstyret som behøvdes for å reprodusere renessansens destilleringsteknikker.

Det endelige målet av rekonstruksjonen var å undersøke utstyret og teknikkens effektivitet, målt med moderne metoder, samt å utforske synergieffekten av å arbeide med teksten parallelt med den faktiske rekonstruksjonen. Rekonstruksjon av historisk utstyr og eksperimenter i alkymi og kjemi har som metodologi vist seg nyttige i flere studier (Holmes and Levere, 2002).

Analysene av det rekonstruerte utstyret viser at noen hypoteser om utviklingen av destilleringsteknologi bør revideres.

Denne oppgaven har vært en del av det flerfaglige Mubil (museum og bibliotek – et digitalt laboratorie)- prosjektet.

Abstract

The *Kreuterbuch* published by Adam Lonicer (1528–1586) in 1569 experienced immense popularity in the 16th century. The book is a lavishly illustrated herbal, in which distillation is a central theme. It has formed the basis for a full-scale reconstruction of distillation processes from the 16th century.

With the aid of specialized craftsmen and -women from the University's workshop a furnace, equipment and glassware needed to reproduce the distillation techniques of the Renaissance were reconstructed.

The ultimate goal of the reconstruction was both to investigate the equipment and techniques' efficiency with some modern methods, and to explore the synergetic effect of working with texts in parallel with the actual reconstruction. The methodology of reconstructing historical equipment and experiments in alchemy and chemistry has showed promise in several studies in history of science (Holmes and Levere, 2002). As Martinón-Torres (2011) has pointed out, there is "a slant in practice-oriented studies towards the metallurgical aspects of alchemy that leaves much room for research on the practical aspects of iatrochemistry".

The analyses of the reconstructed equipment shows that some of the hypotheses concerning the evolution of distillation technology should be revised.

The thesis has been a part of the interdisciplinary Mubil (Museum and Library – a digital laboratory) project.

Contents

Chapter 1

Introduction

The subject of this thesis came about "by chance" when my supervisor, Professor Lise Kvittingen, was contacted by the Head of Section for Cultural and Scientific History at the NTNU University Library (the Gunnerus Library), Stein Olle Johansen, and Project Manager, Alexandra Angeletaki from the Mubil project for assistance with chemistry questions. The main objective of the Mubil project is to make available to a wider public some of the rare and old books in the historic collections of the Gunnerus Library.

1.1 The Mubil project

Libraries with collections of old and rare books seem to have two inherently irreconcilable purposes: to curate the historical artefacts that the books in fact are, and, at the same time, make the books available to the public. The traditional solution to this acknowledged problem is to let the public carefully leaf through books, white-gloved, under the strict eye of a guarding librarian, in the library's reading halls. This unfortunately renders the books all but inaccessible to laymen, and this is why the Mubil project was started.

Mubil is a portmanteau of the Norwegian words MUseum and BIbLiotek, that is *museum* and *library*, and reflects the dual purpose of a historical library. Johansen does however stress that they intend Mubil to be a word in its own right, and not a form of abbreviation or acronym.

The Mubil project was instituted to develop a way of using digital media and modern technology to amend the irreconcilability of these purposes. Many old books from a host of different libraries have already been digitized and published online. Sources like Google Books, Eighteenth Century Collection Online (ECCO), Early English Books Online (EEBO) and Early European Books Online (EEB) give scholars access to large numbers of facsimiles of old and rare books. These "digital libraries" do not, however, offer anything in terms of the "feel" of the books. For example characteristics such as watermarks or the dimensions of the books are obscured in this sort of viewing. The intended function of these digitized libraries is to allow scholars to perform archive research away from the actual archive, and as such they are extraordinarily useful.

These shortcomings of traditional digital publishing of old books was one of the issues Mubil wanted to address, in addition to making the books more appealing and interesting to the general public and to school children in particular. This was to be achieved through a cooperation with PERCO, Scuola Superiore, Sant'Anna in Pisa, Italy and the Department of Computer and Information Science at the Norwegian University of Science and Technology (NTNU).

In the first stage of the Mubil project books were digitized and presented in stacked, digital levels: An augmented layer was designed to catch the eye of the non-scholar reader. In this layer video, audio, animations, and descriptions of the contents of the book help the reader visualize the subject matter. This part is especially designed to create an interest among school children and students. There is also an academic layer where the text can be enlarged and studied, and where transcriptions and translations of the text are available.

One of the first books selected for the Mubil project was the lavishly illustrated *Kreuterbuch* by the German physician and herbalist Adam Lonicer (1528–1586), published in 1569. Among the over 800 woodcuts in this book is a large collection of illustrations of distillation furnaces and distillation equipment. These furnaces and this equipment was the point of discussion when Johansen and Angeletaki from the Mubil project came to the Department of Chemistry. They wanted assistance in both naming and describing the use of this equipment.

Figure 1.1: The pilot in the Mubil project was a digital edition of the book augmented with 3D graphics, audio and video.

My supervisor, Professor Kvittingen, asked me to participate as I have both an interest in history of chemistry and in dissemination of chemistry. When we were shown the illustrations in question my immediate response was that this book would be an excellent starting point for an experimental reconstruction in history of chemistry, thus this thesis was conceived.

As the Mubil project is a dissemination project an important part was to examine how students of different ages would react to and learn from Mubil. Two outreach programs were completed while I was working on my thesis. These offered the possibility to demonstrate how a reconstruction project in the history of chemistry can be a valuable tool in the dissemination of chemistry. This is described in greater detail in chapter 8.

1.2 The thesis

The aim of this thesis is to apply the methodology of reconstructions in history of science to the study of the herbal published by Adam Lonicer in 1557[1], the *Kreuterbuch*. In particular I wish to study, by way of reconstruction, certain aspects of the distillation technology used in the production of medicines in the 16th century. The project is a case study of how the methodology of reconstructions can form a basis for a study in history of chemistry, and will hopefully demonstrate the synergetic relationship between the reconstruction and the historical study.

Thus it can be seen that the objects of this thesis are in fact threefold. Firstly the thesis is a methodological study, documenting aspects of reconstruction as a methodology in history of chemistry; secondly it is a historical study of Adam Lonicer, his *Kreuterbuch* and their place in the history of

[1]The edition I have studied is a reprint that was probably published in 1569 or in 1592. Several editions of the herbal has been published, both during and after Lonicer's lifetime, as will be discussed in the historical study. There is some uncertainty about which year this specific edition was printed.

distillation; and thirdly the thesis aims to uncover certain aspects relating to the distillation equipment used by physicians, apothecaries, alchemists and chemists in the early modern period.

The subject of this thesis is both of historical and of educational interest, and the target audience is therefore not necessarily only the academic scholar in history of science. I therefore ask scholars of history of science to bear with me when I state what may, to them, be obvious. Likewise I apologize to scholars of education for all shortcomings in this thesis with respect to their field. The thesis, I hope, should be read as a thesis in history of chemistry, made accessible to educators and scholars of education, not as a cross-themed thesis of history of chemistry *and* of education.

Along with the traditional presentation of methods for research, master's students are frequently encouraged to specify their methods for searching for relevant literature. As a student of chemistry I was used to describe my methods in a "Materials and Methods" or "Experimental Procedures" chapter. This being a thesis in history of chemistry, albeit with an experimental approach, this would not be a natural way to describe the methods used. In historical sciences methods are usually briefly described in the introduction. However, as the methods I have employed in the present work, in particular the use of reconstructions, have played a central role and do not appear to be very common among most historians of science, I have chosen to start the thesis with a chapter on the methods applied. In this chapter I first describe the methods put to use in acquiring literature, and then proceed to evaluate reconstructions as a research method in history of science.

The next chapters of the thesis are divided into two parts: a historical study of Adam Lonicer, the Lonicer herbal and the role and technology of distillation in the 16th century, and an experimental study of specific parts of the distillation technology described by Lonicer, with a chapter on the educational perspective of the experimental part of this thesis.

In the title of the thesis I have called this an *experimental approach* to the study of distillation. As is evident from the structure of the thesis indicated above, far from all of the work in this thesis is of an experimental nature, however the experimental component has provided a backbone in my approach to the study of 16th century distillation. It has also influenced how I studied Adam Lonicer himself. By following his descriptions and instructions for building the furnace I had a chance to assess how suitable and complete they are. Was any information lacking? Were the descriptions sufficient to complete the furnace and distillation procedures, or did anything seem to be taken for granted or was left out for other reasons?

Having constructed the furnace also gave a more intuitive insight into how the equipment worked and what were the concerns and challenges for the practitioner of distillation in the early modern period. This insight formed a basis for my further studies and thoughts around the thesis. I thus deemed it fitting to title the thesis "*an experimental approach* to the study of 16th century distillation".

The structuring of the thesis into these two parts, the historical and the experimental, may give the impression that the structure of the work has been divided in the same manner. And though they do, in many ways, form disjunctive parts of the actual work, they are inseparably interwoven, and the one would not have been completed in the same way without the other. I would therefore like to stress that experimental reconstruction in history of science is by no means a separate act to the traditional methods of archive research, synthesis and so forth, it is a complimentary act. The structuring of this thesis into a historical and an experimental part is only a literary construct to ease the writing and reading of the thesis.

1.3 Some definitions

For the sake of clarity I will explain some terms that I make use of in the thesis, before I continue with the chapter on research methods. I will also briefly explain my notation for referring to page numbers in Adam Lonicer's *Kreuterbuch*.

1.3.1 Chymistry

In this thesis I sometimes use the terms 'chymistry' and 'chymists'. These are terms that are commonly applied among historians of chemistry and alchemy to denominate both early chemistry and alchemy. A not uncommon modern perception of alchemy is that it was a narrow-minded and often fraudulent pseudo-science, sometimes with magical connotations – a distant and perhaps slightly embarrassing cousin of modern chemistry. However alchemy and chemistry were, in the early modern period, associated with the same pursuits and methods. The application of the early spelling 'chymistry' is therefore often used to collectively refer to these pursuits, and, to a certain extent, to avoid the laden term 'alchemy'. (Principe, 2011, p. 80)

1.3.2 Alembic and cucurbit

The word alembic has different meanings. It sometimes refers to the still head of distillation apparatuses from the early modern period and earlier. At other times it is used as a name for the entire apparatus, that is both the still head and the cucurbit. The term was originally used for the distillation head only, but since the 10th century CE the term has also been used collectively for both alembic and cucurbit (Forbes, 1970, p. 23). ‘Alembic’ is an early form of the word ‘ambix’, meaning ‘pot’ or ‘jar’, and is derived from the Arabic form *al-anbiq*.

In this thesis I will use the word alembic as a name for the still head, and for a collective word I will simply write ‘distillation apparatus’ when I refer to both the still head, that is the alembic, and the cucurbit.

It seems that Lonicer used the term cucurbit, stemming from the latin *cucurbita*, meaning “gourd”, for a specific type of flask for distillation apparatuses. The long and thin flasks he refers to as *Cucurbiten*. As a general term he uses the German *Kolben*, which is still used in modern German and some other Germanic languages, such as Norwegian and Danish, to mean a laboratory flask. To distinguish the *kolben* from modern flasks I will use the term cucurbit for all such flasks, as is commonly seen in both modern and historic treatises on early modern distillation.

1.3.3 Time period

I frequently refer to the Renaissance in the following chapters. The proper name for the time period in question should be the early modern period, or the start of the early modern period. Mainly we are concerned with the time around the life-span of the predominant characters that the thesis is concerned with. First and foremost Adam Lonicer (1528–1586), but also Christian Egenolff (1502–1555) and others. Roughly this constitutes the time from the start to the end of the 16th century. When I write Renaissance, for instance "a brief account of Renaissance medicine" or "the botanical Renaissance", it is often to emphasize a particular cultural or scientific development.

1.3.4 Lonicer's herbal

The term 'herbal' refers to "a book containing the names and descriptions of herbs, or of plants in general, with their properties and virtues" (O.E.D., 2013). In the 16th century herbals were an important form of scientific publication dealing not only with plants, but often also animals, minerals and other natural substances. Some of these herbals dealt almost entirely with methods of distillation, and were often named "book of distillation" in some form or other. Hieronimus Brunschwig's *Liber de arte distillandi* is perhaps one of the most well known examples of these distillation books. (Brunschwig, 1530, p. 45–46) As Lonicer's *Kreuterbuch* deals both with distillation, including recipes for distilled remedies, and with the description of herbs, plants, trees and so forth (also including birds, beasts, fish, minerals, gems, etc.), it can be regarded both as a book of distillation and as a herbal. However, as distillation books can be seen as a sub-category of herbals or as a cross-over of herbal and craft-book (Kunstbuchlein), I will refer to the *Kreuterbuch* as a herbal.

The pages of the *Kreuterbuch* are numbered according to a system known as folio page numbers. To avoid any confusion I should explain what this means: In a folio enumeration every *leaf* has its own number, in stead of every *page*. So the first page of the book, being the first side of the first leaf, is numbered 1, but the second page has no page number as it is the back side of leaf 1. The third is numbered 2 because it is the first side of leaf 2, and so on. When referring to folio enumerated pages the two pages of each leaf are given a designation according to whether it is on the first or second side of the leaf.

A common way of referring to folio numbered pages is to write f1 or f1r for page one and f1v for page two. The *f* indicates a folio style page numbering, the *r* stands for *recto* and the *v* is for *verso*, from Latin meaning *leading* and *turned*, respectively; however, the *r* is often omitted. So f12 would correspond to page 23, the first or leading side of the 12th leaf, and f12v would correspond to page 24, the second or turned side of leaf 12.

The leaves of the *Kreuterbuch* are numbered with Roman numerals, and I have decided to keep these, rather than "translate" them into Arabic numerals. This has been done in order to make it easier to look up references in the book.

Chapter 2

Research methods

> “*The true method of knowledge is experiment*”
>
> William Blake,

In the following chapter I will briefly account for the research methods that have lead to this thesis, with an emphasis on different sources to trace relevant literature. The methods for reconstructing the furnace, equipment and distillation process are described in detail in chapter 7, but I will in the present chapter discuss some advantages and challenges this method presents.

2.1 Literature

Researchers daily have to tackle the task of finding and reading literature such as books, articles, reviews, etc. The skill of navigating between journals and books within various subjects is an integral part of scientific literacy. Consequently the following section contains parts that are obvious to the scientifically trained reader, and I would encourage these readers to skip forward to section 2.1.2 on page 18.

2.1.1 Peer-reviewed publications

The present thesis included the common problem of searching for literature on previous projects; in my case especially projects involving the reconstruction of historical distillation equipment. In contrast to many other research projects there were no obvious loose ends that I could start gathering up.

Several scientists have written extensively on reconstructions, especially in archaeology, but discovering any previous projects in experimental, historical distillation was far from straight forward. Simply searching through the books of acknowledged authors on the subject of the history of distillation was not likely to answer whether anyone, and if so – who, had ever attempted to reconstruct distillation furnaces, equipment or processes. If for no other reason, then because publications on the history of distillation are surprisingly few. As this was one of the most demanding searches for literature in my thesis it illustrates how I have acquired relevant literature. Before I start it is pertinent to point out that in the past few decades the methods for gathering scientific literature have changed considerably. As a student of chemistry I, like most students now, have not been taught to search volumes of Chemical Abstracts or Beilstein, but instead how to use digital search engines to perform both broad and precise searches for literature. Obviously this has both advantages and drawbacks. Nevertheless, I believe that in the case of this thesis it has been an advantage, since the subject and methods adjoin to several different fields, and the sources, especially on the history of distillation, are widespread in time.

To undertake the search for experimental projects in the history of distillation I started on the assumption that if anyone had ever conducted any similar project successfully it seemed most likely that their results would have been reported either in a book or as an article. To trace any such articles several searches were made with the Scopus database, which like ISI Web of Science, JSTOR, Historical Abstracts and others, is a digital archive cataloguing articles, reviews, conference papers, editorials etc. in peer-reviewed journals. Scopus is stated to be the largest abstract and citation database of peer-reviewed literature in the world (Elsevier, n.d.).

Scopus (like most abstract databases) implements the application of Boolean operators. This allows for the formulation of queries that cover as widely as possible; for instance, for documents that mention Adam Lonicer in the title, abstract or keywords several different spellings were covered:

```
TITLE-ABS-KEY(lonicer OR lonicerus OR lonitzer)
```

The returns, in this case, were merely seven documents. Profuse application of the disjunctive operator would however frequently return a vast number of results, too numerous to read every abstract, or even every title. For instance the following search was made to uncover documents containing descriptions of historical reconstructions:

```
TITLE-ABS-KEY((alchemy OR alchemical OR chemistry OR
chemical) AND history OR historical) AND (reconstruction
OR reconstruct OR reconstructing OR reproduced OR reprod-
uction OR reproducing OR experiment OR experimental OR
restage OR restaging OR remake OR remaking OR remodel OR
remodelling OR reproduce OR reproduction OR reproducing)
```

This search returned (at the time) 16,095 documents. The "Analyze results" tool in Scopus shows, unsurprisingly, that the documents cover a wide range of subjects, as shown in figure 2.1[1]. Restricting this to report results that are classified as pertaining to chemistry gave 1,952 documents, 7.7% of the total. A better way however is to use the powerful tool available in Scopus: proximity operators.

The proximity operator, `W/`n, works by specifying the maximum number of words allowed between two search strings. So searching `Arnold W/1 Villanova` would return results for `Arnold of Villanova`, `Arnold de Villanova`, `Arnold Villanova`, `Arnold from Villanova` and any other result where the words "Arnold" and "Villanova" are placed with no more than one word between them. (In this example the proximity operator `PRE/`n could also have been used. This would only return results where Arnold precedes Villanova.)

Using this proximity operator to amend the search described above removes a number of results from the search, leaving only 732:

[1]Note that one document can be listed under several subjects. E.g. an article analysing William Henry Perkin's synthesis of the pigment mauvein in 1856 is both a chemical and a historical article.

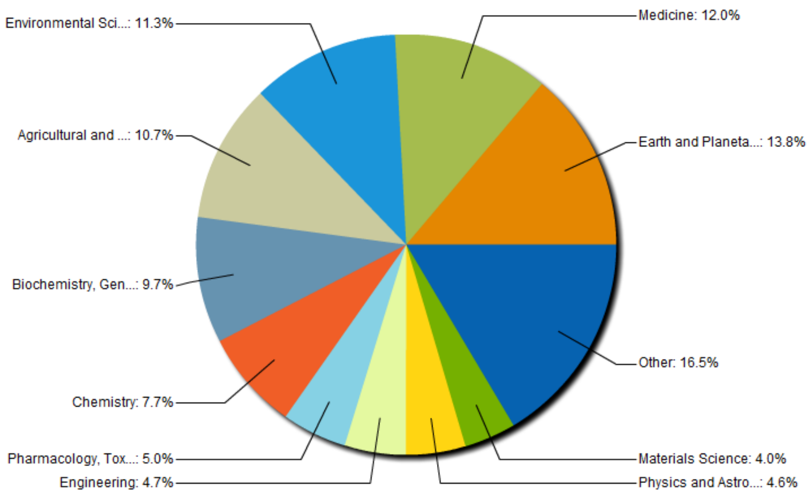

Figure 2.1: Distribution of results by subject from the search described on page 14
Source: Scopus.com

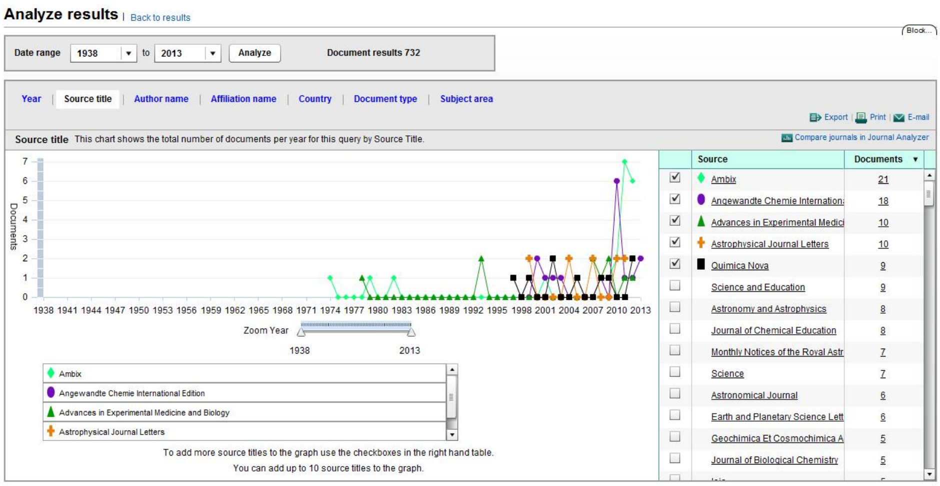

Figure 2.2: Distribution of results between different journals each year. Source: Scopus.com

```
TITLE-ABS-KEY((alchemy OR alchemical OR chemistry OR chemical) w/1 (history OR historical)) AND (reconstruction OR reconstruct OR reconstructing OR reproduced OR reproduction OR reproducing OR experiment OR experimental OR restage OR restaging OR remake OR remaking OR remodel OR remodelling OR reproduce)
```

For a master project 732 is still a lot of results. At least the titles could be covered, however a more fruitful approach was to exploit the “Analyze results” tool once more, this time the “Source title” function, that sorts the documents by journal. As seen from figure 2.2, most documents have been published in *Ambix*, a journal relevant for my type of project.

The fact that a journal (in my case *Ambix*) has the highest number of hits in a search does not necessarily mean that these documents are more likely to be relevant to a project. However the scope of *Ambix* is to publish on all aspects of the history of alchemy and chemistry from early times to the present, which is highly relevant to the subject of my project. In addition to its relevance it also seems likely that if any project relevant to mine has been published in *Ambix* we could expect any further research or comments to this research also to be published in the same journal, thus increasing the number of hits on our search.

The drawback of searching in these kinds of databases is that one is limited to the abstract, title, keywords, authors, etc. of the publications indexed in the database (be it Scopus or any other). A whole range of publications have not yet been indexed, or even digitized, especially considering material of some time ago. This is of course one of the major Achilles heels of acquiring literature digitally: the danger of missing important publications because they are not found in digital form.

This is, at least to a certain degree, alleviated by the systems for listing the citations of digitized literature. This means that if the author of a book or article has cited another book or article that does not exist in digital form, then you will at least find an index file for that book or article. These systems become particularly advantageous when they are paired with the function found in many databases, such as JSTOR: the database will suggest similar or possibly relevant articles to your query based on criteria such as citations, similarities in keywords, statistics for co-visited database-entries (e.g. different documents that have been downloaded by the same user), and so forth.

In the end the only peer-reviewed publication I found of a reconstruction of historical distillation equipment was by the far more manual approach, intimately known to most scientists older than myself, namely in a bibliographical essay. This article is one of many that has not yet been indexed in Scopus (or any other database), and therefore cannot be found no matter how carefully the search is composed, a reminder, at least for my generation, why bibliographic essays should still not be left out as a source for literature search.

Bibliographic essays have several major advantages: Unlike digital databases they are subject-specific and books are included (which is not the case for most abstract databases). Since they are written by a human author, he or she has already done the time-consuming work of finding the literature and deciding what is relevant to the topic and what is not. The author will also have made evaluations of the publications and given thoughts as to the contribution of the work to the research within the subject. Not surprisingly, this makes bibliographic essays important in any literature search.

I should mention that library databases of course also have been employed to acquire literature for the thesis. Predominantly the Bibsys Ask database used by all Norwegian libraries, but also international databases such as WorldCat.

2.1.2 Digital archive research

An important asset for this thesis has been the EEBO (Early English Books Online) and EEB (Early European Books Online) databases. These databases are a collective effort of libraries in England, Denmark, Italy and the Netherlands where all digitized works printed earlier than 1701 are made available. Together with Google Books, which holds books from several libraries and collections around the world, they make a formidable collection of early modern publications that have offered me the possibility of consulting more primary literature in the project than would otherwise have been feasible.

Another important event for my project was the digitalization of Lonicer's Kreuterbuch[2]. This did not only make my work a lot easier, but also made the book available to any and everyone who wish to consult it. As the NTNU University library is not part of the EEB or EEBO projects this digital version of the *Kreuterbuch* is not indexed in their search engine, however the book can be found on the web pages of the University library at `http://www.ntnu.no/ub/spesialsamlingene/ebok/kreuterbuch.html`.

When I in this thesis refer to page numbers in the Kreuterbuch i often report them on the form 'page XL/81'. Whenever I report page numbers in Arabic numerals these refer to the page numbers in the digital version. There are however a few pages missing in the digital version, and to avoid any ambiguity in case these should be re-introduced, changing the page numbering, I have reported the page numbers along with the folio page numbers given in the printed book. On at least one occasion I have reported only the folio page number. This is because the page in question does not exist in the digital version.

[2]Initially the Mubil project only planed to digitize the first chapter of the *Kreuterbuch*
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2.2 Reconstructions as a research method

Reconstructions in history of science seem to have become increasingly popular over the past few decades. Several eminent historians such as William Newman, Lawrence Principe, Otto Sibum, and many others have stood at the forefront of this trend. According to (Staubermann, 2011, p. vii) "reconstructions in the history of science have become a cornerstone of this discipline." Though this may be true for the history of physics the method still seems to be less frequent in history of chemistry.

Reconstructions have a great potential as a compliment to the traditional methods in history of science, and in other historical and archaeological disciplines the method already has a long tradition. In Scandinavia alone we have many examples in the reconstruction of replica ships, such as the famous Kon-Tiki or the replica Viking longboats. The antikythera mechanism has been reconstructed on several occasions. Recently one of many reconstructions in battle history was performed in Leipzig on the second centennial of Napoleons great loss in 1813 in 'the Battle of the Nations' (Spiegel Online International, 2013). These are just a few examples of reconstructions used in various scientific disciplines.

Several motivations and procedures for reconstructions exist. Woodman (2009) divides them into those based on facts, such as iconography or texts, and those based on a "floating hypothesis", that is interpretations of partial evidence. The latter is often the case for reconstructions based on ancient archaeological remains.

There are multiple aims for performing reconstructions, both in history of science and other sciences. One that is not uncommon in history of science, and perhaps more so than in other sciences, is reconstructions for teaching purposes. Reconstructions of both experimental designs, devises and processes are used in education in both schools and universities. Some, like the Daniell cell or the Thomas Young interference experiment, are more common than others; however, even an experiment as challenging (at least to perform) as the Voltaic pile has been reported used as a student experiment (Eggen et al., 2012).

Several other aims for reconstructions have been outlined. A common goal for reconstructions is to gain a better understanding of the historic artefacts. Hopkins (2011) calls this "to answer the *unanswerable*". Uncovering ergonomic aspects of an artefact, sensations experienced in its use, smells and sounds are a few examples of these "unanswerables". These insights can also be valuable in understanding the accounts of these artefacts and their use. They can help us to form insights not only into the practical knowledge of the artefact, process or experiment, but also into the social and cultural aspects. The recreation of both an apparatus and the associated process can change our understanding of the apparatus in what Staubermann (2011) calls an epistemic reallocation. To exploit these advantages the German historian of science H. Otto Sibum has even established dedicated research groups and projects for 'Experimental History of Science' at the Max Planck Institute and at the University of Uppsala (Sibum, 2007; Uppsala Universitet, n.d.), where replicated experiments are systematically employed as a complementary means to study science historically.

An obvious downside to reconstructions is the fact that they can be costly and are usually very time-consuming. Furthermore replicas can demand more space than that available in a university laboratory or office.

The educational value of a replica is also limited by the cost and location of the replica (perhaps only one replica is insufficient to demonstrate its function to an entire class or student group?). Virtual reconstructions are a form of reconstruction that are under constant development to alleviate these problems; however, there is still an important short-coming to virtual reconstructions: the limited possibility of interaction. Although technology is improving, and Mubil has taken a large step towards making an interactive virtual reconstruction of 16th century distillation, the experience as to actually operate a real live distillation furnace is still far from the same. According to Gauvin (2012) this view is supported by Michael Wright, creator of the well-known replication of the Antikythera mechanism:

> Wright emphasizes the learning value of making a 3D replication in preference to a computer animation, since the latter does not take into account issues of mass, inertia, weight, strength, stiffness and working loads. It is the inconvenience of these physical forces, and how one solves them, that produces true hands-on knowledge.

Finally I will round off this section by drawing the reader's attention to a wording that Bill Thayer (2006) of the University of Chicago has used when he once transcribed the full *Naturalis Historia* by Pliny the Elder: he found it "an instructive exercise much like that of the musician who copies Bach". In fields of study where tacit knowledge is more obviously embedded in the knowledge required by its students and practitioners, reproduction is often used as a tool for gaining new insights, skills or understanding, be it painting, music or architecture. I believe that chemistry and the history of chemistry, with its many manual secrets and general appeal and demand to the senses, and not only the intellect, could naturally fall into the group above.

Part I

Historical study

Chapter 3

Adam Lonicer: Physician and printer in Frankfurt am Main

> “*The distillation of herbs and of other simplica and composita have many usefull applications*”
>
> Adam Lonicer,

In this part of the thesis I will try to sketch an image of the German Renaissance physician Adam Lonicer (1528–1586) and his enherbal, titled *Kreuterbuch: künstliche Conterfeytunge der Bäume, Stauden, Hecken, Kreuter, Getreyde, Gewürtze: mit eygentlicher Beschreibung derselbigen Namen, Underscheidt, Gestalt, natürlicher Krafft und Wirckung ... sampt distillierens künstlichem und kurtzem Bericht.* I will refer to it simply as the *Kreuterbuch.* I will in this part attempt to situate both the man, Lonicer, and his œuvre, the *Kreuterbuch* , in their contemporary society and in the history of distillation. To do this I will first outline some aspects of Adam Lonicer himself, expand into discussions about distillation, printing and medicine in the Renaissance, before returning to Adam Lonicer again in the final chapter of this part.

3.1 Adam Lonicer – a short biography

Figure 3.1: Adam Lonicer, by Theodor de Bry (mid-17th century)
Source: ©National Portrait Gallery, London

Adam Lonicer was born i Marburg on October 10th 1528 into a reformist family. His father, Johannes Lonicer (Mägdefrau, 1987), theologian and philologist, collaborated with Martin Luther (1483–1546). Luther assigned him to respond to a polemic, *Super apostolica sede*, written by the Franciscan Augustin Alveld (*c.* 1480–1535) in 1520, one of the most prolific of the early opponents of the reformation. Johannes Lonicer's response *Contra Romanistam fratrem Augustiniu* (Lonicer, 1520), was "a vicious personal attack designed to refute Alveldt's arguments by ridiculing his pretensions to theological expertise" (Brown, 2005). Several letters document the contact between Johannes Lonicer and Luther, also in Johannes' later life. S(Horawitz, 1884)

As the son of one of Luther's collaborators and a resident of the city where the first protestant university was founded in 1527, it was perhaps a natural choice for young Adam Lonicer to start his further education at the Marburg University.[1] At the age of 13 he had finished his Baccalaureate and started his Magister degree at Marburg and Mainz, which he finished three years later.[2] He was then given a teaching position at the gymnasium in Frankfurt am Main, but returned to Marburg the following year, due to war and unrest in the region. (Stricker, 1884)

It is not uncommon to come across the statement that Adam Lonicer was taught by the Swiss physician and naturalist Conrad Gesner[3] (1516–1565). Gesner was, for educational reasons, raised by his great-uncle, who collected and grew herbs for medical use and thus gained an early interest in plants and herbs. His work on the systematization of plants and animals has been long lasting. In Zürich he is commemorated with statues both in the botanical garden and outside the Central Library. Gesner devoted much time to teaching and held teaching positions both in Zürich, Lausanne and at the Collegium Carolinum, however it is difficult to find sources that can

[1]Incidentally the University of Marburg was also the first university to have a professor of chemistry, or 'chemiatry', as it was called, only 23 years after Lonicer's death. Today chemiatry would be called iatrochemistry. (Stafford, 2009)

[2]Lonicer seems to have been a very young student. He was certainly younger in age than many other prominent 16th century scholars, like Martin Luther, who started university at the age of 19, Nicholas Copernicus (1473–1543), who was 18, or Galileo Galilei (1564–1642) and Johannes Kepler (1571–1630) who were both 17 .

[3]E.g. Donaldson (2011a).

substantiate the claim that Lonicer was among his students.

In 1551 Lonicer took up a post as the private tutor to the children of the physician and professor of mathematics Wilhelm Osterrod (Roth, 1902). Around this time he also published two books, *Arithmetices brevis introductio* (Lonicer, 1551a) and *Naturalis Historiae Opus Nouum* (Lonicer, 1551b) at the publishing house of Christian Egenolff (1502–1555) in Frankfurt am Main. The latter is a Latin predecessor of the *Kreuterbuch*.

Adam Lonicer's contact with Egenolff and the Egenolff publishing house might have started already in his childhood, when his father, Johannes Lonicer, published *Graecae Grammaticae methodus* (Lonicer, 1536). According to Horawitz (1884) this work was published by Egenolff in Frankfurt, but the 1536 editions of this book available from digitized book databases appear to have been published by Basileae (apud Barptholomaeus Uvesthemerum et Nicolaum Brylingerum), and not Egenolff. Nevertheless, the 1540 edition clearly was from the Egenolff publishing house (Lonicer, 1540), and Johannes Lonicer published several other works thereafter before the younger Lonicer, Adam, also started publishing his books at Egenolff's. Adam Lonicer's connection with publishing and with the Egenolff house was to become much more tightly knit in the following years.

In 1553 Lonicer took a post as a professor of mathematics at the University of Marburg, where his father was professor of Greek and Hebrew (Thomas, 1870, p. 1451). It has been speculated that his previous employer, Professor Osterrod, may have played a part in Lonicer's acquisition of this post (Roth, 1902)[4]. While Adam Lonicer was teaching at Marburg

[4]A point in the argument is the fact that Lonice's education was in medicine and not mathematics. However frequently in the 16th century the teaching of mathematics

he also finished his medical studies, and in 1554 he became a doctor of medicine (M.D.). The same year he also obtained the post as town physician in Frankfurt after the death of the previous one, Eucharius Rösslin[5]. This must have been an eventful year for the 26 year old Lonicer, because in the same year he also married Magdalena Egenolff, daughter of the printer, Christian Egenolff[6]. Christian died early in 1555, leaving the responsibility of the printing house to Lonicer and his, Christian's, family. (Stricker, 1884)

3.2 Christian Egenolff and the printing industry

Egenolff is an interesting character in his own right. His work and business exemplifies publishing industry at the time, which in turn may help to better understand the herbal tradition to which *Kreuterbuch* belongs, and as the ties between Egenolff and Lonicer as well as between the *Kreuterbuch* and earlier herbals printed by Egenolff are so strong (this last fact shall be

was regarded as lower in status than other academic studies (Galilei is a widely quoted example of this) and the teaching of mathematics in the universities was often left to young scholars rather than senior professors (Johnston, 1996).

[5]Some sources seem to disagree with Rösslin being the previous town physician of Frankfurt. The origin of this discrepancy is probably the *Allgemeine Deutsche Biographie* (Stricker, 1884) which claims that a dr. Graff, who also died in 1554, preceded Lonicer as town physician. This has later been cited, e.g. by Figala (2008). The available biographic material concerning Eucharius Rösslin seems to be clouded by the fact that he was named after his father, Eucharius Rösslin (*c.* 1470–1526), renowned for his publication of the textbook for Midwives, *Der schwangeren Frauen und Hebammen Rosengarten* (the authorship of this work has lately been questioned (Kruse, 1994)), and confusion of identity between the two appears to have occurred.

[6]According to Anderson (1997, p. 157) the marriage took place on the same day as he obtained his doctorate

demonstrated in section 3.3) a study of Egenloff and his publishing house is warranted as a part of the study of the *Kreuterbuch*.

Figure 3.2: Woodcut of Christian Egenolff (1502-1555)
Source: Wikimedia Commons

The advent of the printing press in the mid 15th century opened up to the possibility of mass production of books. This industrialisation of publishing provided, in the words of Marshal McLuhan (2011, p. 142), "the first uniformly repeatable commodity, the first assembly line, and the first mass production". It has been estimated that there had been published at least 35,000 editions totalling at the very lowest 15-20 million books in Western Europe by the year 1500 (Febvre and Martin, 1997, p 186).

Egenolff started his publishing business in Strasbourg in 1528, but two years later he moved it to Frankfurt, an important city for the book industry due to *The Frankfurt Book Fair* which had, for many years, been a central institution in the German book industry. However no publishing house had been established in the city before Egenolff started printing there in 1530. (Weidhaas, 2007, pp. 46–47)

The publishing house of Christian Egenolff was very successful. It has been noted that Egenolff must have had a keen sense of business (Arber, 1912, p. 64), and he certainly was prolific in his production. In addition to printing books he also manufactured the lead types used by the printers. During his 25 years as a Frankfurt printer more than 400 titles were published (Weidhaas, 2007, p. 46–47). His extensive use of illustrations, made by skilled block-cutters in what is described as a "fluid, decorative style that made extremely attractive books" (Anderson, 1997, pp. 156–157), and the relatively low prices of his books (ibid.) may have been key elements in his success. However, as will be described later, his use of woodcuts would also cause him trouble.

Egenolff has been called "an innovator in technical publication" (Eamon, 1994, p. 114) and has been claimed to have printed the first of the so-called *Kunstbüchlein*, the *Rechter Gebrauch d'Alchimei* (The proper use of alchemy) in 1531[7]. The publishing of this book is usually credited to Egenolff, although no publisher is mentioned. There are however strong indications that the work was printed by Egenolff (idem pp. 2–3). Particularly the printers devise on the title page, identical to that of Egenolff's, is convincing.[8]

Künstbuchleins were a genre of book that became popular in the 16th century. They contained technical information and descriptions of crafts (Eamon, 1994, p. 114). In the *Rechter Gebrauch d'Alchimei* transmutation is mentioned (Ferguson, 1906, p. 8), but the book is not on "speculative or transcendental alchemy" (Ferguson, 1888, p. 3). The recipes are aberrantly plain and unconcealed in their descriptions of ingredients and processes (ibid.). In this aspect the work could be considered to be an early example

[7] Among others Eamon (1994, p. 114) and Brunello (1973, p. 179)

[8] It should be noted that one of the indications that Ferguson relies on is the typeface used in the work and its similarity to other publications by Egenolff around the same time. It should be remembered that Egenolff, as mentioned above, produced types for printing and can easily have provided these to other printers. However the printers device on the titlepage makes it likely that he in fact is the publisher of the work.

of the alchemical tradition that would later follow from the metallurgists Georgius Agricola (1494–1555) and Vannoccio Biringuccio (1480–*c.* 1539), known for distancing themselves from fraudulent and secretive alchemists.

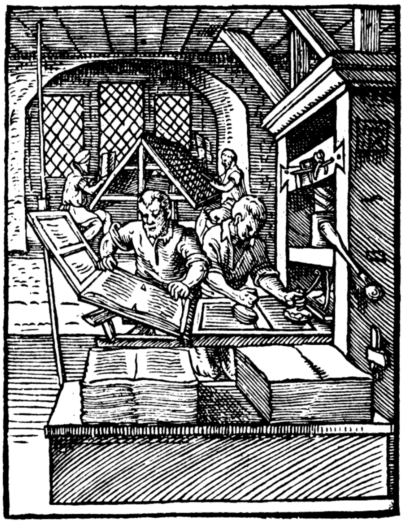


Figure 3.3: A printing press from 1568, as portrayed by Jodocus Amman (1539–1591)
Source: Wikimedia Commons

The collection of *Künstbuchlein* presented by Ferguson (1888) is probably the origin of the statement that the *Rechter Gebrauch d'Alchimei* was the first of the *Künstbuchlein.* In the treatise Ferguson described a form of book that became common in the 16th through 18th centuries "dealing with the marvels of nature, with popular science and medicine, and with practical receipts for domestic and workshop use" (Ferguson, 1888, p. 1). Some of these he considers to stand in a closer relationship to each other, and these are presented chronologically in the treatise. The first of these is the *Rechter Gebrauch d'Alchimei.* It seems probable that this has been taken to mean that this was the first of the *Künstbuchlein*, however the only statement made is that it is the first of the *Künstbuchlein* that share a closer relationship. Other, earlier works from the same era also fit the description Ferguson gives, like the *Liber de arte Distillandi*, first published in 1500 by the Strasbourgian physician and chymist Hieronimus Brunschwig (*c.* 1450–*c.* 1512).

Undoubtedly Egenolff was a profusely productive printer of *Künstbuchlein*. Apparently he became "the largest and most famous publisher of vernacular scientific books" in Germany in his time (Eamon, 1994, p. 107). The careers of writers who published scientific and technological works in the vernacular were accelerated by their association with Egenolff, perhaps none more than his son-in-law, Adam Lonicer. The prominent alchemist and surgeon Walther Ryff (*c.* 1500–1548) was employed as a house author with the Egenolff publishing house for three years from 1544, producing no less than ten exceedingly popular books including a treatise on distillation (idem p. 109). The bloom of the Egenolff publishing house coincided with a surge in popularity of both technical and botanical literature in the vernacular. During this period Frankfurt was one of the leading publishing cities in Europe (Weidhaas, 2007, p. 47). In 1550 Egenolff's publishing business had thrived sufficiently for him to expand and he opened a new department in Marburg, where he became the official printer for the University (Eamon, 1994, p. 109). Upon his death Egenolff left his business to his heirs. Adam Lonicer became the director of the publishing house (Forbes, 1970, p. 138), though others of his heirs were also involved in the firm (Mägdefrau, 1987). The publishing house kept the Egenolff name until 1667. The business was by then one of Germany's most successful publishing houses. (Eamon, 1994, p. 109)

There are many reasons why the Egenolff firm became so successful. The move from Strasbourg to Frankfurt was undoubtedly an important reason, the extensive use of the vernacular may have been another. One hallmark of Egenolff publications that may also have contributed to their success was the pervasive use of rich illustrations. It was not uncommon for printers in the 16th century to reuse and reprint both texts and woodcuts from other works, and this kind of practise landed Egenolff in a lawsuit in 1533 (Eamon, 1994, p. 110). The Strasbourg printer Johann Schott filed a suit against Egenolff for using, in a herbal by Eucharius Rösslin, a set of particularly good woodcuts made by Hans Weiditz for Schott's publication of Otto Brunfels' herbal *Herbarium vivae icones*. This was the first reprinting case in the Holy Roman Empire. After first having called into question the competence of jurisdiction of the court (the case was filed at the Imperial Chamber Court, but Egelolff claimed he had a right to have the case tried before his local judge in Frankfurt) (Kawohl, 2008), Egenolff argued that nature itself could not be plagiarized, and that he could not illustrate the plants and herbs in any other way, because it would depart from nature. He also claimed that the main influence for the herbal was not Brunfels' herbal, but an earlier herbal by Johannes de Cuba, a 15th century Frankfurtian physician. In any case, Egenolff argued this use of previously printed works was justified by the great value to the society of herbals in pestilent times. (Koerner, 1993, p. 215–218) There does not exist any records of the verdict in this case, but it has been conjectured that Egenolff lost the case based on the fact that the very same woodcuts he used in Rösslin's herbal later was used by Schott in an edition of Brunfels' *Herbarium vivae icones*[9] (Kawohl, 2008; Arber, 1912, pp. 209–210).

As an important Renaissance publisher Egenolff contributed to the dissemination of technical and botanical literature to the public. However it is

[9] Egenolff's set of woodcuts can be distinguished from the original Weiditz woodcuts in that they have been scaled down.

important to note that the dissemination of technical and "learned" knowledge in the vernacular did not erase the boundaries between the learned and other parts of society, though it did contribute to the exchange of information over cultural and social barriers (Eamon, 1994, p. 94).

For a more complete account of Christian Egenolff's life and business I refer the reader to "Christian Egenolff, 1502-1555: ein Frankfurter Meister des frühen Buchdrucks aus Hadamar" by the *Kulturvereinigung Hadamar*.

3.3 Lonicer's Kreuterbuch

Egenolff was well known for publishing books in the vernacular, however he also published many in Latin. Lonicer's 1551 publication, Naturalis historiae opus nouum (1551b), was one of these. In 1557, after he had inherited the publishing house, Lonicer published a German, vernacular version, namely the *Kreuterbuch*, which we are concerned with here.

One of the first things to note about the *Kreuterbuch* is that, in contrast to many other herbals published after 1530, it does not open with an index (Koerner, 1993, p. 215). This index was present in the *Naturalis historiae*, but has not been included in the vernacular version. These indices did not only list the names of the entries in the book, but also list cross-references to ailments that could be cured with remedies from the book. It could be speculated that the absence of the index in the vernacular version is related to the fact that a professional physician, one who could need this kind of index in his profession, would be proficient in Latin, and would not use a vernacular book in performing his craft. However it is difficult to validate such a conjecture.

The original sources for the knowledge presented in *Kreuterbuch* are various ancient philosophers. Among the entries some refer to the Greek physician and pharmacologist Pedanius Dioscorides (*c.* 40–*c.* 90) and his *magnum opus*, the *De Materia Medica*, for instance the description and pharmacology of juniper, where Lonicer also cites Dioscorides in the description:

> But as many wish / it is denominated Iuniperus /quòd iuniores & nouellos fructus pariat.[10] As only this among the trees carries its fruits almost into the second year / which also do not ripen / when already new ones are growing. Two families of it are described by Dioscorides / namely / the large and the small / both have pointy narrow leaves / that always are green.
>
> (Lonicer, 1569, p. fXL/81)

Other entries refer to Pliny the Elder, like the entry concerning the phoenix. Though Lonicer does not cite Pliny in the text, the content is so similar to Pliny's description (*Naturalis Historia*, book 10, chapter 2) that it seems likely that it stems from him.[11]

Lonicer also cites several more recent authors on distillation and herbals. Among them Valerius Cordus, Hieronimus Brunschwig and Conrad Gesner. In addition to these the *Kreuterbuch* bears several strong similarities to other, previous herbals. It is evident in examining copies of a

[10] as it brings forth younger and new fruits

[11] Interestingly Lonicer does not add the reservation that Pliny adds in saying that he is uncertain whether this bird exists or whether it is just a fable.

Phœnix.

PHœnix ist ein Vogel in Arabia. Dieser Vogel lebet fünffhundert Jar / oder länger / So er dann sihet / daß er alt worden ist / samlet er viel wolrieckender Specerey kreuter / vnnd macht ein hauffen / vnd fehret hoch vbersich zu der Sonnen glantz / vnd mit dem Wind seiner Flügel macht er jhm ein Feuwer / vnd verbrennet sich darinnen / vnd stehet widerumb von der äschen lebendig auff.

Solinus: Bey den Arabischen wirdt der Vogel Phœnix in der grösse eines Adlers / mit einem schweren haren Kopff vnd auffgereckten Federn / einen harten Schnabel / am Halß güldinfarb / am hindertheil Purpurfarb / vnd am Schwantz / der mit Rosenfarben Federn getheilt wirdt / scheinet er geel Wasserfarb.

Figure 3.4: The phoenix is one of several fable creatures that can be found in the *Kreuterbuch*
Source: Lonicer (1569), p. fCCCXLII/685

previous Egenolff-published herbal, penned by Eucharius Rösslin in 1533[12], and republished at least once in 1540 (Hohenlohe-Zentralarchiv Neuenstein, 2013), that Lonicer's *Kreuterbuch* should be regarded as a work compiled from previous herbals (Arber, 1912, p. 64). Both wording and illustrations are often identical to Rösslin's herbal, although Lonicer seems to have expanded or rewritten sections. In modern day terms a grievous example of plagiarism, but not just an outright copy. As mentioned in the previous section, this was not uncommon at the time. In fact Rösslin's herbal was, as mentioned, based on a herbal by Johannes de Cuba, a town physician in Frankfurt at the end of the 15th century. If compared to the works of

[12]This was the aforementioned publication in which Egenolff plagiarized the Hans Weiditz woodcuts from Otto Brunfels' herbal published by Johann Schott.

Walther Ryff, published while he worked for Christian Egenolff, we find that some of the woodcuts were used in other works than the herbals as well. An example is shown in figure 3.5.

Figure 3.5: Many of the illustrations in Lonicers *Kreuterbuch* have been borrowed from other herbals and books of distillation. On the left, a page from Lonicer's *Kreuterbuch*, and on the right, the first page of Ryff's *Destillier Buch* published by Egenolff in 1545

Source: Lonicer (1569, p. fVII/17), and Kunstauktionen Hassfurther, `www.kunstnet.at`, respectively

On the first few pages Lonicer states that his motivation for publishing the book is the fact that distillation has by now become so prevalent a practise that even the poorest can distil several common herbs. Moreover, the distilled waters have several useful applications, such as potent medicines, and it is exceedingly advantageous, particularly to the poor, to be able to distil medicines. Lonicer continues with a brief account of distillation in general. Its discovery is, he writes, relatively new. It was unknown to the ancient Greeks and Latin physicians. (Lonicer, 1569, pp. fI/1–fIv/2) He also notes similarities between distillation and how water is evaporated from the earth by the sun and then rains down again, and how the liver heats up the inner vapours of the body which rises to the head, akin to the alembic, and runs out the nose as “snot and slime” (ibid. p. fIv/6) .

Lonicer’s narration of the discovery of distillation is interesting because it is an example of a kind of historiographic model that can sometimes be found in the late Middle Ages and early modern period. It describes invention or discovery as something driven by chance. It is not the idea of serendipity that has been reported many times in modern science (Roberts, 1989); serendipity would also imply sagacity (Kvittingen, 1997). Lonicer here narrates how discovery of distillation is thought to have happened:

> “Many say / that the distillation of the waters from the herbs / was accidentally invented by a doctor / who let boil Roman cabbage / that is / beet / and put it in a bowl / and set it on the table / But when he due to a business could not immediately set himself to the table / he covered the herb with another tin bowl / so it should keep warms. As he came to the table / and lifted the first bowl / he saw / that the top bowl was full of moisture and water drops / which had drawn itself from the herb / of a similar taste and odour as the herb / So he thought about this and had made vessels of lead and tin / in which he put herbs / and placed in the heat on a furnace / and tried / if he might

> bring out the juice through the heat of the fire / and when he was successful in such a simple manner / he thought better and more industrious / and thus it developed from day to day / by him and others ingenious tricks, furnaces and instruments / the longer the subtler it became."(Lonicer, 1569)

Lonicer is not the only example of this kind of this kind of model where discovery is made by chance. Another example is the Florentine chemist Antonio Neri's retelling of the discovery of glass as put forward by Pliny the Elder:

> "Pliny saith, that Glass was found by chance in Syria, at the mouth of the river Bellus, by certain Merchants driven thither by the fortune of the Sea, and constrained to abide there, and to dress their provisions making fire upon the ground, where was great store of this sort of herb which many call Kali[13], the ashes whereof make Barillia, and Rochetta; This herb burned with fire, and therewith the ashes & Salt being united with sand or stones fit to be vitrified is made Glass:" (Neri, 1662)

After his account of the origin of distillation Lonicer describes, over the next 26 pages with close to one hundred illustrations, how to build several different distillation furnaces and how to use them for different purposes

[13]It seems likely that this may be the prickly saltwort, also known as prickly glasswort (*Salsoda kali* ssp. *kali*), that grow on salt water-beaches. Due to its high salt content the prickly saltwort has been used in soda production. [http://www.luontoportti.com/suomi/no/kukkakasvit/sodaurt-no]or [http://en.wikipedia.org/wiki/Glasswort]

ranging from the poor-man's variety, consisting of a tripod over a fire, to large gallery furnaces for production of several different distillates at the same time.

Many of the descriptions are very detailed. There are, for instance, extensive instructions for creating the mould for shaping bricks and for the placing of bricks in brick bonds ,that is that one brick should overlap the joint between two bricks in the row below. (Lonicer, 1569, p. fIII/9–fIIIv/10). In other parts of the descriptions he is much more vague. Like the fact that he never specifies the size a distillation furnace should be. Many of the descriptions and instructions concern operational tips, like tools that can be used for emptying waterbaths (idem p. fV/13) etc. Others specify technical aspects of the furnaces and equipment, like the shape of the grilles for the burning embers that should have a triangular cross-section so the ashes runs off easily (idem p. fIIr/8), or the shape of the recepium that should have a conic top to increase surface area in order to increase condensation of vapours inside the flask. (idem p. fIIIIv/12).

After the chapter on distillation Lonicer writes a chapter on the keeping of gardens and of planting: "Von baumung der Garten und pflanzung der Baume". The next chapter, "Von Baumen und Stauden" is the first of several chapters concerning the appearance, nature, medicinal uses and other uses of plants. The chapter describes 117 different trees and bushes, most of which are illustrated.

The structure of each entry is more or less the same for all plants, trees and bushes in the *Kreuterbuch.* First Lonicer describes the botanical characteristics: Latin and Greek names, along with other vernacular names, appearance, bloom, geographical distribution and so on. Then a description of the "Natur oder Complexion" of the plant, which is a classification of the plant[14] and its parts (leaves, root, bark, petals, berries, etc.) into the four qualities: dry, moist, hot or cold. This form of classification has a long history in philosophy and many different terms have been used to describe these 'qualities'. In Hippocratic philosophy they are called 'elements' (Lloyd, 1964), Avicenna calls them 'primary qualities' (Avicenna, 1973, p. 45)[15], and Galen treats them as contrary qualities, and he also uses quasi-quantitative grades (I.E.P., 2014) which can also be found throughout the *Kreuterbuch*: "Pears / [. . .] / are cold in the first grade" and "[T]he peel of the orange is dry in the third grade" (Lonicer, 1569, pp. fXXVI/53 and fXXXv/62, respectively). This classification into qualities in the *Kreuterbuch* is followed by a pharmacological description of the plant's "Krafft und Wirckung" (power and effect). For some of the plants this is followed by one or more descriptions of preparations such as 'waters', 'oils' and 'pastes' ("Gummi"), that can be made from the plant, and how these should be administered against specific ailments.

The last of the entries in this chapter on trees and bushes is of anecdotal interest as it concerns the so-called '*goose tree*', that was thought to bear geese! Several other authors reported this legend that was believed by many to be true at the time. Agnes Arber (1912, pp. 130–134) retells this legend and some of its chroniclers in an epistle that is well worth the read.

[14] I will from here on use 'plant' as a collective term for 'plant, bush or tree'.

[15] It is frequently seen that some call the 'primary qualities' '*temperament*' when referring to Avicenna (e.g. (Aliasl and Khoshzaban, 2013)). By 'temperaments' Avicenna does not refer to the qualities 'hot', 'cold', 'moist' and 'dry', but something that "results from the mutual interaction and interpassion of the four primary qualities". (Avicenna, 1973, p. 57)

It has been suggested that the inclusion of fabulous creatures and stories such as that of the barnacle goose, the dragon, the phoenix and the bezoar contributed strongly to the popularity of the *Kreuterbuch* (Anderson, 1997, pp. 160–162).

Kreuterbuchs Erster Theil/ꝛc.

Sie machen auch weiter darauß ein Siropel wider die Wassersucht/ auß kletten/ wann e es trücknet sehr auß die frätigkeit. Es ist auch gut widers dreytägig vnd viertägig Feber.

Entenbaum/ Entenmuscheln/ Anatifera arbor, Anatiferæ Conchæ. Cap. cxvij.

ZVm beschluß dieses Texts von den Bäumen/ Stauden/ vñ Hecken/ muß ich hinzu setzen vñ beschreiben/ die Historiẽ von dem Entenbaũ/ das ist/ von dem Baume/ auß welcher frucht lebendige Entẽ/ so zur speise gebraucht werdẽ/ erwachsen.

Vnd es lautet wol lecherlich vnd ohnglaublich das Enten oder Vögel auff den Bäumen sollen wachsen / Wie in der Schottländischen Historien gemeldtet wirdt/ vnnd wie auch darvon Olaus Magnus, in dem neuntzehenden Buch seiner Mittnacht ländischen Historien schreibet/ Nemlich/ daß in den Inseln Orchadibus, in Schottenlandt / Bäume seyen an dem Meer / auß welches früchten / welche sein wie kleine Muscheln / wann sie in das wasser oder Meer fallen/ Enten herauß schliefen / welche bald hernach fliegel gewinnen/ vnd zu den anderen zamen vnd wilden Enten fliegen.

Wiewol dieses gar wunderbarlich vnd seltzam lautet / so ist es doch nicht ein Fabel/ sondern bestehet vnnd erfindet sich also mit der warheit / vnnd es bezeugen auch solches die Angli in jrem Kreuterbuch/ daß sie es selbst also gesehen haben.

D

Figure 3.6: The '*goose tree*' was thought to bear geese, in the same way that other trees bear fruit

The above-mentioned three chapters constitutes the first part of the *Kreuterbuch.* After this comes the second part which constitutes one long chapter on "herbs", that is plants that are not trees or bushes. This chapter covers over 400 pages and contains 429 different plants, again most of them illustrated. The structure of each entry is more or less the same as for trees and bushes, with the exception that the section on “Natur oder Complexion” is far less frequent than in the first part. This second part of the book is then followed by the “last part”. This contains chapters on animals, including entries on blood, bile, milk, cheese, butter, and so on. Various animals are described, including man, domestic animals such as cow, goat and horse, common European wild animals such as stag, elk, otter and fox, African animals like lion and elephant, and fictive animals, such as unicorn, dragon and basilisk. Some reptiles and insects are treated in this chapter as well. The next chapter concerns birds, included entries on eggs, honey and beeswax. Among the birds another fictive animal is described, the phoenix, as mentioned above. The chapter on birds is followed by one on fish.

The last three chapters are not grouped together in a part, although they form a separate group from the other chapters in the book. The chapters are (in order) on metals and “earths”, on gems and finally on various “rubbers” and hardened fluids.

In total the herbal contains more than 800 woodcuts, all of which have been hand coloured. Even though there are many editions of *Kreuterbuch* that are not illustrated they are still an impressive sight, and it is not surprising that the herbals from the Egenolff publishing house gained the level of popularity that they did. The herbals printed by Egenolff and Lonicer, from the Rösslin editions to the later reprints of Adam Lonicer’s *Kreuterbuch* became by far the most popular of the herbals published in the botanical Renaissance in Germany (Arber, 1912, p. 64).

Chapter 4

A brief account of some aspects of Renaissance medicine

> *The art of medicine consists of amusing the patient while nature cures the disease*
>
> Voltaire,

In the following chapter I will very briefly deal with some aspects of what one might call the infrastructure of medicine in the 16th century. How was the availability of doctors; in what way were the herbals and distillation books used; and how did the educational system in medicine work. I will deal primarily with the pharmacological aspects of medicine as well as the social side of the medical infrastructure of the early Renaissance. I will not go into other sides of medicine, such as for instance surgery and anatomy. This is by no means an attempt to document the full extent of pharmacology and social medicine in this era; that would be the work of several volumes. I will simply outline a few points that we will need for some of the conclusions I make in chapter 6. 6 on page 73.

4.1 Education and medical knowledge

A lot of the medical knowledge Adam Lonicer would have learned during his studies at Marburg and Mainz stemmed from the Greeks. In particular the *De Materia Medica* by Dioscorides is an important antecedent of Lonicer and his *Kreuterbuch. De Materia Medica* was the most influential work on pharmacology until the 16th century and was prolifically reprinted. (Encyl. Britannica, 2014b)

From the Alexandrian period onwards the dominant texts in medical curricula in European universities were works written by or based on the works of the Greek scholars Hippocrates (*c.* 460–*c.* 375 BCE) and Galen (129–*c.* 216 CE), along with works by Avicenna (Ibn Sina, 980–1037), a Persian polymath who wrote extensively on medicine, astronomy and philosophy.

The Arabs also had their share of influence on European medicine. Perhaps most notably through Avicenna. He wrote several works, but the one that became most influential was *The Canon of Medicine* (*Al-Qanun fi al-Tibb*)(Maclean, 2002, p. 29), claimed to be "among the most famous books in the history of medicine" (Encyl. Britannica, 2014a). We know that Lonicer owned a copy of this work along with an index of its contents. (Donaldson, 2011a) The index, a comprehensive reference to the effects of the medicaments in the main work, seems to have been acquired two years after the *Canon* (Donaldson, 2011b). It is not unlikely that these works have been an aid to Lonicer in his practice as a physician, though he will not have used these exact copies in his university studies, as they were purchased two and four years, respectively, after he qualified as a physician.

Another important Arab contribution stems from the Carthaginian Constantinus Africanus (*c.* 1020–1087) (Flood, 1976). He came to the school of Salerno around 1060, where he worked and translated the works of Arab scholars and Arab translations of previously lost scholars like Hippocrates and Galen (Encyl. Britannica, 2013a). The school of Salerno in Italy was to become important in 'botanical therapy' in medicine (Flood, 1976), as well as in the history of distillation.

University training and licensing were required to practice medicine in most of Europe in the early modern period. It varied greatly from place to place what authority would grant these licences, and the systems of medical regulation were far from uniform. In addition many practitioners of medicine had no formal training, and many also practised medicine without a licence or guild membership. With a demand exceeding the supply of medical assistance, almost as many practitioners in medicine were unlicensed (Siraisi, 2009, p. 19–20).

The school of Salerno in Italy was the first medical school in Europe. Before the inclusion of medicine in the university curricula it was considered as a craft; however it was quickly acknowledged as a respected academical discipline. This led to a division of medical practitioners into two different classes: the academically schooled physicians from the universities and the laymen who remained an important source for medical care up to the 18th century (Schummer et al., 2007)[1]. The medical schools of Europe and the medical faculties at the universities gradually gained a more important role during the early modern period, although many places, among them the German universities, medicine was of less significance than other faculties.(O'Malley, 1970, pp. 89–91)

Although the curriculum at the various medical schools became more standardized during the 16th century there were debates and disagreements on what students should read. Some, like Hippocrates, Galen, Rhazes (al-Razi) and Avicenna were a matter of course, and also studies of herbs and their medicinal properties were common. These studies were greatly facilitated by the increased availability of books in the 16th century. Particularly Galenism was propagated by the new and cheaper books.(O'Malley, 1970) During the 16th century disputes arose in the medical societies between how medicine should be understood. The orthodox Galenic medicine, based on the balance between the body's humours was challenged by the new Paracelsian medicine, introducing minerals and alchemy into medicine. (Wear et al., 1985, p. 115) Galenical pharmaceuticals were generally prepared by physical processes such as extraction or infusion, and medicines were thought to cure "by contraries" (Parker, 1915), according to the temperaments hot, cold, dry, and moist.

[1]It could be argued that the layman medical practitioner in fact never disappeared, and that this function still exists today as the multi-billion pound industry of alternative or 'complementary' medicine.

Galen had been the major authority i European medicine for 200 years when his teachings were challenged, most notably by the Swiss physician and alchemist Paracelsus (Philippus Aureolus Theophrastus Bombastus von Hohenheim, 1493–1541). Paracelsus repudiated the orthodox academic medicine and introduced the idea that sickness came from an imbalance between body and nature. Likewise, harmful properties in substances came from contaminations in substances that were otherwise wholesome. This meant that virtually any substance could be turned into a medicine by distillation, fermentation and other processes. The primary components of all substances were the *tri prima* Mercury, Sulphur and Salt. (Principe, 2011, pp. 82–83) Thus the Paracelsian pharmaceuticals were to a much larger extent based on minerals and chymical processes. Unsurprisingly, Paracelsianism was opposed among academic physicians, and only three universities had Paracelsus on the curriculum: Erfurt, Copenhagen and Marburg, and these, it seems, only did so because they were pressured to do so from outside academic circles. The Protestant courts tended to support the Paracelsian reformation in medicine and would therefore lean on the universities to embrace Paracelsus in their curricula.(Maclean, 2002, pp. 27–28)

Even though Paracelsus has been credited with introducing chemical or alchemical methods to medicine (e.g. Parker, 1915 or Siraisi, 2009, p. 193) it should not be forgotten that both these schools of thought relied on distillation as a method for preparing pharmaceuticals, something which may have been a factor in the surge in popularity for books on distillation during the 16th century.(Wear et al., 1985, p. 115)

Lonicer 1569, p. fI/5 tells us already on the first page that distillation was ubiquitous and it is certainly well described in conjunction with both the medical profession (e.g. Lonicer, 1551b, French, 1651 or Brunschwig, 1530) and the apothecaries (e.g. Cordus, 1575). However it is interesting to note that in a collection of woodcuts published in Frankfurt in 1568 by Schopper depicting a multitude of trades and occupations ranging from Pope and Emperor to clergymen, physician, apothecary, Siftmaker, cooper, ropemaker, and even rusticus and beggar, neither the physician nor the apothecary (pp. B4 and B5, respectively[2]) are depicted with equipment for distillation. The apothecary seems to have sifts and pots on the shelves, rather than vials and bottles, and the physician is depicted handing over a bottle of medicine to a patient[3]. This may indicate that not all apothecaries and physicians used distilled remedies. At least that distillation perhaps wasn't an iconic endeavour for physicians and apothecaries.

Whether an iconic practice or not, the market for books of distillation and herbals certainly was considerable, and many different herbals were printed several times to accommodate the market, as discussed above. With the increased production of books and lowering of costs of books medical knowledge (along with many other forms of knowledge) were spread faster and wider than before.

In this way the Frankfurt book fair (along with the other large book fairs in Europe) played an important role in the dispersion of medical knowledge. As a physician the book fair would have been a valuable source of literature for Lonicer, and as a publisher he would perhaps have been in a better

[2] In the digitized version available through the ProQuest Early European Books database these are images 52 and 54.

[3] According to Schummer et al. (2007) this common representation of the physician did at some point in the late Middle Ages shift to that of a physician studying a glass of urine for diagnostic purposes. The two motifs can be difficult to distinguish.

position to acquire literature than many others. Many were unable to visit the fair and had to send agents to do their purchases for them. Lonicer on the other hand, being a Frankfurter, would not only have easy access to the fair, but as a publisher he would be able to participate in the so called *Tauschhandel*, where publishers would swap equal amounts of printed sheets. The importance of the fair must have been great, for the fair is said to have determined the debate on disputed issues in both public and academic circles. (Maclean, 2002, p. 48)

The medical literature available at the book fair consisted of books on surgery, handbooks in treatment and medical astronomy, distillation books, herbals and pharmacopoeia. Of these the herbals and books of distillation are of the ones that are of interest to us, so I will refer the reader to other sources, such as Siraisi (2009) or Maclean (2002) for further details on other medical literature.

4.2 Herbals and books of distillation

If we are to believe the accounts of the English physician and herbalist William Turner (*c.* 1508–1568), who published the first herbal in English, a herbal was a vital tool for the scholars and physicians. He expressed outrage at the lack of knowledge among English scholars and physicians on the area of herbs, trees and plants. (Arber, 1912, pp. 121–123)

Most of the early herbals were purely utilitarian, that is they were made according how they could be of most use to man. Herbs were arranged and described according their qualities as pharmacological substances or other traits that made them valuable. (Arber, 1912, p. 264) However even as early as in Dioscorides' *Materia Medica* a morphological structure emerged, making the herbals works of botanical science and not just pharmacological lexica.(Parker, 1915)

The arrival of the printing press in the mid 15th century, allowing for easier, faster and cheaper production of books, also became a steppingstone for the botanical book illustration to gain popularity. Arber (1912, p. 268) places the height of the botanical book illustration to the period from 1530 to 1614, beginning with the woodcuts of Hans Weiditz in Brunfels' *Herbarium vivae eicones* and ending with the copperplates of Crispian de Passe in *Hortus floridus* by Pena and de l'Obel.

This is the height of what she calls "the botanical Renaissance". The most important German authors of this botanical Renaissance are Otto Brunfels (*c.* 1488–1534), Hieronimus Bock (1498–1554) from and Leonhard Fuchs (1501–1566). Brunfels primarily for the woodcuts by Hans Weiditz, which are "incomparably better than the text, which is very poor, and largely borrowed from other writers." (Arber, 1912, p. 50) This then perhaps goes some way to explain Christian Egenolff's temptation to pirate the woodcuts in the herbal by Rösslin, as discussed in section 3.2. The accomplishment of the botanical Renaissance was to "move botany away from medieval herbalism, with its trtadition of folklore, toward its emergence as a modern science." (Encyl. Britannica, 2013b)

Brunfels, Bock and Fuchs, among several other northern European herbalists were of the reformed faith, as Lonicer also seems to have been. It has been suggested that this inclination to an independence of thought is in some way connected to these writers ability to rationally 'weed' their works of dogmas and doctrines that were of a superstitious nature: Ideas such as astrological methods for healing or the doctrine of signatures, where likenesses in a plant to parts of the human body would be taken as a concealed sign from God that the plant held healing powers for that particular part of the body. Rather, these reformed herbalists held 'a healthy scepticism, in which they were in advance of their time' (Arber, 1912, p. 266)

The development of botanical science was not solely for the purposes of the academic advancement. Many medicines were produced from plants, and William Turner whom I mentioned at the start of this chapter was not alone in thinking that the herbal knowledge even among physicians was appalling. Leonhard Fuchs stated in the preface to the Latin edition of his herbal, *De historia stirpium*, that "it is scarcely possible to find one [physician] among a hundred who has an accurate knowledge of even so many as a few plants" (Arber, 1912, p. 60).

The growth in botanical research, coupled with the advancement of anatomical knowledge (famously extended by the Belgian physician Andreas Vesalius, 1514–1564), has been called "the medical Renaissance of the sixteenth century" (Siraisi, 2009, p. 193), and though this catalysed the eventual replacement of Aristotle and Galen as the foundation of medicine the herbals and materia medica still retained an important position much longer (ibid.).

Chapter 5

Alchemy, chymistry and the evolution of the art of distillation

> "*Many have said of Alchemy, that it is for the making of gold and silver. For me such is not the aim, but to consider only what virtue and power may lie in medicines*"
>
> Paracelsus,

We have now studied the *Kreuterbuch* from a literary and a medical point of view. Before we return to Adam Lonicer and the *Kreuterbuch* again, we should also outline some important aspects of the history of distillation as well. However, as distillation is closely linked to alchemy and the alchemists, and alchemy in its turn is linked to some parts of early modern medicine, we have to take a short detour into this area as well.

With respect to alchemy it is important to address what appears to be a prevalent view of alchemy, both amongst laymen and some historians; namely that alchemy was confined to the futile endeavours to transmute base metals into gold, or to create the panacea that is often called the philosopher's stone. This perception of alchemy is so well rooted that it may affect the interpretation of the link between alchemy and distillation technology.

Many historians of science in the mid-twentieth century shared this view of alchemy, as demonstrated by Allen G. Debus (2006, see chapter 1) in his short epistle on how the scholars of the history of science have flocked to the study of the scientific revolution. Alchemy, with its affiliation to mysticism and the perceived claim of transmutation were completely at odds with the paradigms of modern science, and was thus discarded as pseudo-science, more or less irrelevant to modern science and the history of modern science. Debus (2006, p. 2) points to George Sarton[1] as an example of this view and cites his *Introduction to the History of science*:

> the historian of science can not devote much attention to the study of superstition and magic, that is, of unreason, because this does not help him very much to understand human progress.

[1]Sarton made an effort to institute guidelines for the research in the history of science in-which progress was an important factor. The value of historical research in science lay only in the documentation of progressive, "systematized positive knowledge" that is of relevance to contemporary or future knowledge. (Kragh, 1987)

Cited in (Debus, 2006)

Though this may be an extreme example illustrating why alchemy has been shunned by some historians, it is still the case that the historiography of the last century has in the last few decades been criticized for having taken a quite relativistic (to borrow a phrase from social anthropology) approach to the documentation of alchemy and the alchemists.

This means that the perception and presentation of alchemists are viewed is strongly influenced by modern science and modern thought without accommodating a decent degree of the world-view in which the alchemists lived. Take as an example transmutation: In modern science we know that base metals cannot be transmuted into gold (save perhaps in an extreme particle acceleration experiment). We know today that to 'transmute' silver into gold 32 protons would have to be added to its nucleus along with electrons and neutrons to make up a stable isotope. To accomplish this through a normal chemical reaction, especially one involving or relying on mystic rituals, incantations and the like is nonsensical. However the alchemists did succeed in producing reactions where metals appeared to take part in transmutational

Figure 5.1: In the chemical garden-reaction minerals appear to grow like an organism
Source: Wikimedia Commons, ©2010, Nevit Dilmen.

reactions, and even seem to come to life and grow like an organism.

William R. Newman of the University of Indiana demonstrated two such reactions in an excellent lecture at the Perimeter Institute in Waterloo, Ontario in 2010. The full lecture was entitled *"Why Did Isaac Newton Believe in Alchemy"* and is available online[2].

Above I have argued for a more generous attitude to alchemy among modern historians. However, one should not forget that the controversy surrounding alchemy is by no means a creation of the 20th century. Satire and irony of alchemy can be traced far back, even to the 14th century. An example commonly referred to is the poem "The Canon's Yeoman's Tale" by the British writer and polymath Geoffrey Chaucer (*c.* 1343–1400). In this poem a Canon's servant brags about his master's abilities as an alchemist (lines 620–626):

I seye, my lord kan swich subtilitee –
But al his craft ye may nat wite at me,
And somwhat helpe I yet to his wirkyng –
That al this ground on which we been ridyng,
Til that we come to Caunterbury toun,
He koude al clene turnen up-so-doun,
And pave it al of silver and of gold.

or in a modern translation:

I say, my lord knows such esoteric science –
But all his craft you can not know from me,

[2]William R. Newman on Why Did Isaac Newton Believe in Alchemy: `https://www.youtube.com/watch?v=NUhL1cli4ug`

And yet somewhat I help in his work –
That all this ground on which we are riding,
Until we come to Canterbury town,
He could turn all completely upside down,
And pave it all with silver and with gold.

(Benson and Chaucer, 1987)

The poem, particularly the prologue, attacks the fraudulent alchemists who claim to be able to make gold and the author bluntly states that the multiplication of gold is unachievable and alchemists who say otherwise are swindlers (Benson and Chaucer, 1987, lines 668-679). However Chaucer's language, his use of imagery like "His forheed dropped as a stillatorie" (line 580), along with his thorough descriptions of alchemical processes (see lines 754–781 below) has lead historians to speculate whether Chauser was not in fact an accomplished alchemist himself, and that it was only the swindlers and charlatans that he attacked in the poem (Damon, 1924).

Why should I tell each proportion
Of the things that we work upon –
As on five or six ounces, it may well be,
Of silver, or some other quantity –
And busy myself to tell you the names
Of orpiment (arsenic trisulfide), burned bones, iron flakes,
That are ground into very fine powder;
And how all is put in an earthen pot,
And salt put in, and also pepper,

763 *Before these powders that I speak of here;*
764 *And well covered with a lamp-shaped vessel of glass;*
765 *And of many other things which were there;*
766 *And sealing of the pot and glasses*
767 *So that not a bit of the air could pass out;*
768 *And of the slow fir, and fast also,*
769 *Which was made, and of the care and woe*
770 *That we had in purifying our materials,*
771 *And in blending and reducing to powder*
772 *Of quicksilver, called raw mercury?*
773 *Despite all our tricks we can not succeed.*
774 *Our orpiment (arsenic trisulfide), and purified mercury,*
775 *Our litharge (lead monoxide) ground also on the porphyry mortar,*
776 *A certain number of ounces of each of these –*
777 *Nothing helps us; our labor is in vain.*
778 *Also neither our spirit's vaporization,*
779 *Nor our materials that remain fixed in the pot,*
780 *Can in any way help us in our working,*
781 *For all our labor and travail is lost;*

(Benson and Chaucer, 1987)

Here I have only given the translated text, but those interested are recommended to read the original version of the poem, which is far more poetic. (The Middle English version of the extract above can be found in appendix D on page 151.)

It is certainly true that Chaucer writes in a way that suggests the possibility, even likelihood, that he was personally familiar with alchemical practices. His descriptions of how the vessel is luted together, the experiences of working the fire and his overall knowledge of alchemical terminology and processes hint at an intimate knowledge of the art. The poem has by several historians been taken as an actual account of alchemical practices in Chaucer's age[3]. (Walker, 1932; Fox, 2010; Damon, 1924)

This then serves as a good example that in the 14th century there were alchemists who disgraced the reputation of the art, and that this reputation has stuck with alchemy ever since. This is also important to bear in mind when we consider the alchemical aspects of early modern medicine. As discussed in the previous chapter the orthodox medicine based on the works of Galen, Hippocrates, Aristotle and Avicenna was challenged by Paracelsus. Paracelsus was himself an alchemist, like many medical scholars of that time. And even before Paracelsus many of the processes applied in the production of medicines and remedies were taken from the alchemists. Lonicer mentions this relationship to alchemy on the first two pages of the *Kreuterbuch*:

> The distillation of herbs and of other simplica and composita / have many useful applications / since it can in many ways produce / different noble medicines / that can be used in a beautiful way /for many most heavy infirmities / as is recounted

[3]It should also be noted that several literary scholars view the alchemical aspects of *The Canon's Yeoman's Tale* as metaphorical and a means to moralize (Herz, 1961, e.g.), and Grennen (1965) even states that "the curious misconception of Chaucer's personality which more than once in the past led readers to the belief that he was himself an adept at alchemy ought finally to be laid to rest".

/ elaborately in the treaties on distillation and alchemy

(Lonicer, 1569, pp. fI–fIv/5–6)

The attempts to vindicate alchemy and establish it as a part of natural science and philosophy have been documented from at least as early as the late 14th–early 15th century (Grund, 2009). The Italian polymath Giambattista Della Porta (*c.* 1535–1615) was one of the well-known alchemists who repudiated the charges against the art. Porta has been called "the Italian Brunschwygk [*sic.*]" (Forbes, 1970, p. 117) and is an important character in the history of distillation. He wrote that despite alchemy being much slandered it should be "embraced and much sought after" (Eamon, 1994, p. 164).

5.1 Distillation

As the history of distillation is the history of the distillation apparatus I will only deal with the history of distillation very briefly in this part. This is in order to place put the history into the context of the reconstruction in part 2.

Arguably one of the most important and long-lived legacies of alchemy in chemistry is the art of distillation. Since there has not been written any comprehensive history of distillation since the mid 20th century (Forbes, 1948, republished 1970) it can be difficult to get an overview of distillation history and how knowledge about it has progressed in the last decades. Forbes introduces his volume on the subject with a surprised statement of how little research has been done on this subject. More than half a decade later the situation is much the same. Historians have written epistles on the history of distillation, but no work has come close to being as extensive as Forbes' *A Short History on the Art of Distillation*. Still there have emerged some new arguments, and many of the hypotheses that Forbes refutes are still pervasive. I shall therefore try to give a short summary of some of the dominant and regularly encountered hypotheses, and provide a comment on these.

However before I embark on this summary of hypotheses it is necessary to emphasize that there is a danger of ambiguity in discussing early distillation. The term 'distillation' has taken several definitions through its history, and it seems that some authors differ in what they define as distillation. Both filtration and sublimation have been considered as distillation techniques at some point in history.

There seems to be a historiographic prerequisite that both an understanding of the most fundamental principles of distillation as well as recognizable distillation apparatus has to be documented before it is accepted that a civilization or a society has been familiar with distillation. Thus, the tar kilns used for dry distillation of pine wood in Fennoscandina (predominantly modern day Norway, Sweden and Finland) as early as the Roman Iron Age(Hjulström et al., 2006), is generally not discussed in the history of early distillation. This may be because there was no documented understanding of distillation principles. Distillation apparatuses existed in the form of kilns dug out of the ground (figure 5.2).[4]. On the other hand, Aris-

[4]It should be noted that the tar kiln also lack continuity with other forms of distillation technology. It would therefore not be possible to say that these kilns are antecedents of later distillation technology, even though they pre-date other forms of distillation in this

totle's descriptions of the principles of evaporation and condensing of water that can be used to make fresh water from sea water is not recognized as an early form of for distillation because evidence suggests that he never used any apparatus that applied these principles.

Figure 5.2: A tar kiln in Öland, Sweden
Source: Wikimedia Commons

The exact beginning of the history of distillation is subject to much debate. In the attempts that have been made over the past century to

area and were used up to well after distillation technology was introduced. (Distillation of *aqua vitae* in Norway has been documented in the 16th century).(Hjulström et al., 2006; Bille, 1531) describe the history of the art many different approaches has been taken, and many different arguments made, reasoning why distillation must be anything from thousands of years old to having been invented around the second century CE.

There are various different theories as to how, where and when distillation was first invented, some of the most common are listed here [5]:

- Distillation has been invented independently in many different cultures. Variations on this view are reported by Crawley (1912, cited by Forbes (1970), p. 4) and Doxat (1971, p. 80)
- The ancient Egyptians were the first to invent distillation more than 1500 years BCE, commonly with reference to the *Ebers papyrus* (Krell, 1982, p. 20).
- Distillation emerged in Alexandria around the first century CE (Forbes, 1970)
- The Chinese were the first to discover distillation (Hyams, 1965, p. 226)
- Distillation was an Arabian invention (Patrick, 1970, p. 29)
- Persians were the first to discover distillation in their production of rose water (Schelenz, 1911, cited by Krell, 1982, p. 20)
- Traces of early distillation can be found in India/Pakistan from around the beginning of the common era (Ghosh, 1948; Marshall, 1951)

[5] I will not detail all of these. That would be the work of several volumes

The history of distillation has often been said to begin with Aristotle. In his *Meteorologica* he describes the principles behind distillation and states that these principles can be applied to seawater to make fresh water. However we have no evidence to support a claim that Aristotle ever could or did distil anything.

Some chemists seem to think that the art or technique of distillation is very old. It is not uncommon to come across the statement that distillation was practised over 5,000 years ago (e.g. (Weires et al., 2011) and (Greenberg, 2007, p. 144)). However, the generally accepted time and place for the emergence of the art of distillation is around the first century in the Hellenist milieu in Alexandria. The argument for this view is that the first documented description of a distillation apparatus was made by Mary the Jewess in Alexandria around this time. This view certainly appears to be the most extensively argued in the history of distillation (Forbes, 1970), though hold Mary's contemporary Cleopatra of Alexandria (not the Pharaoh of the Ptolemaic dynasty) as the first to document a distillation apparatus (Liebmann, 1956)

With some few exceptions, such as Dioscorides' sublimation in *De Materia Medica* (as illustrated in figure 5.3), the art of distillation seem to have been mainly practised by the (metallurgical) alchemists over the next first centuries of the common era (Liebmann, 1956). Around the 12th century in Salerno, Italy the distillation of alcohol was first discovered. Forbes (1970, p. 89) states, as a matter of course, that the inefficient cooling and poor separation in the ancient stills was the reason for the late discovery of alcohol. The distillation should produce a distillate of around $30\%_{v/v}$ for it to

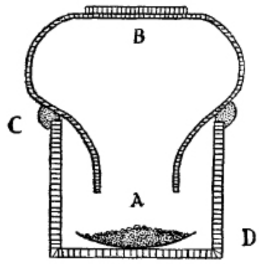


Figure 5.3: A conjectured restoration of the mercury-distilling apparatus of Dioscorides
Source: (Taylor, 1945)

make a cloth burn[6], what was called *aqua ardens*, burning water (ibid.).

Alcohol gained a position as the best medium for preparing distilled pharmaceuticals. It was thought highly potent and it seems that there is a connection between the Black Death and the use of alcohol in Europe (Forbes, 1970, p. 91). The distillation of alcohol was an important motivation to develop more efficient stills (Forbes, 1970).

Around the middle of the 13th century the Florentine alchemist Taddeo Alderotti (Thaddeus Florentius, *c.* 1210–1295) at the University of Bologna first published a treatise in which he describes the cooling of the still head with water, however this would not become common for another 200 years (Lydersen, 1986).

Before the advent of water cooling the most efficient way to cool a still head was by insuring that it had a great surface area so the heat could be

[6]This is easily verifiable in a laboratory, but the results may vary if it is attempted somewhere with a draft, i.e. in a fume hood or outside.

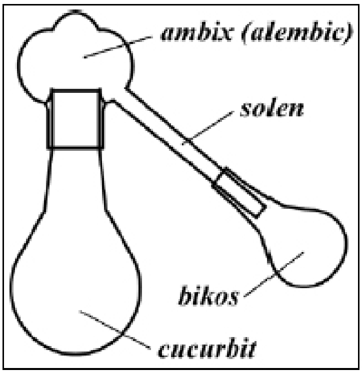


Figure 5.4: The common structure of early distillation apparatuses. In this thesis I use the Latin names for the 'solen' and 'bikos': *'rostrum'* and *recepium*
Source: (Rasmussen, 2008)

transferred to the air. This was achieved with the so-called *Rosenhut* (figure 5.5) (Forbes, 1970, p. 83).

The early stills were primarily made from clay or copper. With the advent of improved technology for the production of glass it became increasingly common to make stills of glass. This made it easier to produce efficient, water cooled alembics (so-called *Moor's heads*, see figure 5.5) (Rasmussen, 2008).

I will leave the rest of the discussion on glassware and distillation equipment to chapter 7, where it will be put into the context of the reconstruction.

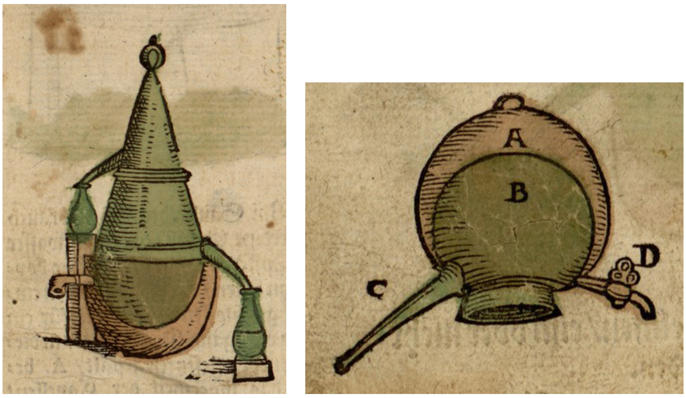


Figure 5.5: On the left a *Rosenhut* for distilling two different fractions at once. On the right a *Moor's head* with a basin or jacket containing water that cools the alembic

Source: (Lonicer, 1569, p. fIIIIv/12)

Chapter 6

Conclusions from the preceding chapters applied to the case of Adam Lonicer's *Kreuterbuch*

The chapters in this part have presented a framework within which Adam Lonicer's *Kreuterbuch* can be interpreted. In this chapter I will present some conclusions that can be extracted from these chapters concerning Adam Lonicer and his *Kreuterbuch*.

The *Kreuterbuch* was printed at a time when there was a boom in the book industry. Since the advent of the printing press the sales of books increased exponentially and Christian Egenolff managed to navigate this market expertly. Both his herbals and his *Kunstbüchlein* have earned their places in the history of vernacular scientific publishing, and Egenolff is claimed to have been the largest printer of vernacular, scientific books in Germany in his time (Eamon, 1994, p. 107). His abundant use of illustrations may have contributed to the popularity of his publications, although his unlaudable practice of reprinting woodcuts lost him a lawsuit he still continued to "pirate" form other works (Arber, 1912, pp. 209–212). Nevertheless the herbals that issued from the Egenolff publishing house were among the most popular in the vernacular in Germany. This practise of reprinting may even have been an attempt or a strategy to sell more books by giving the impression that new works were being produced (Anderson, 1997, p. 156).

Adam Lonicer's *Kreuterbuch* is one of the most prominent books to have emerged from the Egenolff publishing house. The Egenolff publishing house was a very valuable inheritance when Lonicer became director of the firm (Mägdefrau, 1987), and according to Anderson (1997, p. 157) it increased in value after he began publishing his editions of the *Kreuterbuch*. This means that aside from any academic or disseminative purposes for publishing the *Kreuterbuch* the remuneratory motive must also have been strong.

In its contents the *Kreuterbuch* is, to some extent, like most of the early herbals, what Arber (1912, p. 264) calls utilitarian. That is, its primary function is to remedy disease and disseminate the knowledge of preparation of medicines. The structure of the work is shaped to this purpose: it opens with a chapter on distillation, describing the craft and tools needed for the preparation of medicines, and for almost all the plants throughout the book the "Krafft und Wirckung" are presented, along with instructions on how to prepare and use remedies from the plants.

Nevertheless, the herbal also has a morphological structure based on the one introduced by Dioscorides (Parker, 1915). Plants that are similar in appearance and properties are grouped together in a pre-Linnaean classification system. In conjunction with the chapters on animals, birds, fish, gems and minerals, it is equally justifiable to classify the work as a lexical book documenting nature. The afore-mentioned absence of an index of remedies and illnesses, that was typical of many 16th century herbals, could be understood in this context as an indication that the *Kreuterbuch* was in fact more a herbal than a book of distillation. The distillation chapter relies heavily on the *Book of Distillation* by Brunschwig (1530), both in structure and contents, but Lonicer have left out the less "useful portions" (Anderson, 1997, 157–158) making the distillation chapter an abridged introduction to distillation rather than a comprehensive documentation of the craft.

The pharmacognosy of the *Kreuterbuch* can be traced back to the teachings of Galen, who was the primary authority on medicine in the mid 16th century. Lonicer's listings of "Krafft und Wirckung" where the different parts of each plant is categorized according to Galen's four qualities with the four quasi-quantitative grades for differentiation:

> The grade of the qualities / of which the natural teachers write / are four / of either secret or obvious changes. At changes in the first grade nothing is seen / the second little / the third noticeably / the fourth practically distructive / through a noticeable change / either in food / herbs / or medicines
>
> (Lonicer, 1569, p. XIIIIv/30)

The "simplica and composita" that Lonicer mentions on the first page of the distillation chapter, and that I have previously referred to, are testaments to the *Kreuterbuch's* Galenical legacy. Galen's *On mixtures* was the work where he describes the four qualities and the grading of them, and *On Simples* was Galen's work on drugs (I.E.P., 2014). The preparations and recipes in *Kreuterbuch* are mostly Galenic, that is they are made by various extractions and distillations, and are not composed from minerals, such as many of the Paracelsian drugs.

This places Lonicer, as a physician in the orthodox, Galenic tradition. At this time Galen was still the dominant authority in medicine, though the Paracelsian influences on medicine had already started at Lonicer's time. The critique of the orthodox medicine from Paracelsus and others did eventually contribute to the reformation in medicine, but initially the medical community was appalled by Paracelsus' repudiation of Galenic medicine and his teaching of medicine in the vernacular (Arber, 1912, p. 248). In this last respect Lonicer and Paracelsus had common interests and as a reformist Lonicer may have moved in circles that were supporting of Paracelsus, but Lonicer himself does not appear to have been a Paracelsian.

While the medical content of Lonicer's *Kreuterbuch* can be traced back to Galen, the intellectual work, the texts and woodcuts, also has roots other than Lonicer. It is difficult not to conclude that Lonicer's *Kreuterbuch* has an intellectual lineage that can be traced back to Johannes de Cuba, through Eucarius Rösslin, to Otto Brunfels and Leonhard Fuch, as well as to Hieronimus Brunschwig and the alchemist Walther Ryff, the latter two in the distillation chapter. Not only woodcuts but text and structure can be recognized on comparing these authors. Agnes Arber has not obscured her opinions on the practice of 'piracy' that the Egenolff publishing house represented:

> *They do not reflect any great credit on Egenolph, since they were mostly pirated from Brunfels. [The illustrations] were not even used to illustrate a new herbal, but merely a new edition of the of the old German Herbarius, enlarged and improved by Dr Eucharias Rhodion*[1]*, and issued under the name of 'Kreuterbůch von allem Erdtgewächs.'*

(Arber, 1912, p. 64)

Treatises on herbal history often assert the blatant piracy of some of the publications from the Egenolff publishing, with less attention devoted to the fact that this was a common practice (Arber, 1912; Anderson, 1997, for instance), and that publications of for instance French (1651) show illustrations that clearly have the same lineage as those in the *Kreuterbuch*. As Egenolff was involved in what is referred to as the first copyright case in the Holy Roman Empire, for infringement of the Imperial privilege granted to Johann Schott for the Brunfels herbal (Kawohl, 2008), Egenolff may perhaps have been less respectful of other printers than the average 16th century printer. However it is also possible that he is held i a particularly low esteem because he has this suit to his name.

Nevertheless that is not to say that the *Kreuterbuch* does not hold any place of importance in the history of distillation. The immense popularity of the *Kreuterbuch* stimulated the dispersion of knowledge of distillation

[1] Arber often favours the Latinated spelling of names, like Rhodion for Rösslin or Egenolph for Egenolff.

to a large audience. Whether this actually caused some to receive medical treatment that otherwise would not is difficult to ascertain. There are indications that herbals were kept as a, to some extent, active part of domestic medicine (Leong, 2008)[2], but since the *Kreuterbuch* is “prescriptive”, that is, we do in fact know very little about how it was used in both medical and social context, and by whom (Siraisi, 2009, p. xi).

[2]The study in question is a case-study from England a period some 150 years after Lonicer. We should be careful not to blindly transfer the results from this study to the case of Lonicer; however it is interesting to note that herbals of the form Lonicer helped make popular have resulted in active, medical use.

Part II

Experimental study

Chapter 7

Reconstruction

> “ *In this regard processes and procedures themselves acquire the status of artifacts, or real historical objects* ”
>
> Bruce T. Moran, *Distilling Knowledge*, 2005

This chapter will concern the reconstruction of the furnace and the equipment used in the historical experiments. As discussed in chapter 2.2 reconstructions of historic, scientific equipment, processes and experiments can be a valuable tool in the study of history of science. In the case of this project the reconstruction served as a starting point and a backbone to the study of Lonicer's herbal. Both by being a source of questions and as a structural basis.

In addition the reconstruction both conscientiously and subconscientiously affects how we read literature, which literature we look for and which parts of the literature we take special notice of. For instance, my attention would perhaps not have been drawn to the Chinese and Mongolian stills if I had not come across the article by Butler and Needham (1980). This article is the only account I have come by that describes the analytical reconstruction of ancient distillation equipment. Or I would perhaps not have taken notice of the fact that Lonicer (1569) gives virtually no specifications of sizes and dimensions in his herbal, while Brunschwig (1530) suggests ideal sizes for each part of his furnaces.

The argument has been made that before embarking on a reconstruction, as much information as possible should be gathered about the artefact, devise, process or experiment in question (Höttecke, 2000); however, I would argue that this effectively separates the reconstruction from the initial phases of the research. The reconstruction will still be the "ultimate goal", and this will have the aforementioned affect on what literature is used and how; however if we would be able to plan for every eventuality and study all parts of the object of reconstruction quite completely beforehand, then we are in danger of reducing the reconstruction to a curiosity performed at the end of the "proper research". Many of the synergetic effects of working with reconstructions and traditional research are lost.

In my case, the process of reconstructing the furnace led to many new questions that would have been difficult to foresee. I have already mentioned the question of dimensions, but other practical aspects, such as the availability of glassware, methods of luting the glassware, procedures for handling the glassware, etc. were all questions that were a lot more obvious after the construction was commenced.

Each cucurbit ordered from the university glass-blowers had to have an alembic that fitted. If one were to break, the other would no longer have a matching opposite. In the *Kreuterbuch* Lonicer describes simple glass works to fuse glassware and implements to to cut glass (Lonicer, 1569, pp. XII–XIIv), so it seems likely that it may have been more or less common for chymists to perform adjustments to glassware themselves. We know that some early chymists were glass-makers (more on this in section 7.2.1), but most practitioners of distillation were probably not, at least not of profession. However it may have been an important part of the skill-set of a distiller to be able to adjust or fuse glassware.

Figure 7.1: A simple glass works to adjust or fuse glassware
Source: Lonicer (1569)

The question of luting is also an interesting one. When he describes the wooden lid for covering the sand- or waterbath Lonicer writes that the holes should be cut painstakingly accurate around the cucurbit (Lonicer, 1569, p. 8/IIr). However, later he writes that in order to protect the glassware it should be wrapped in thick cloth of wool or, if a sandbath is used, be completely covered with lute. If the cucurbit should be covered in wool or lute, then it is not clear why the holes in the wooden lid should be so accurately made.

Another interesting point to make concerning the luting of glass vessels is the fact that none of the dozens of illustration depict a luted vessel. This could have any number of reasons: the artist may not have seen an actual distillation, or he might have decided that the illustration would be clearer if the lute was omitted, or it may have been a form of romanticism, in that anything considered “ugly” was left out of the illustration or doctored to look better. In any case, there seem to exist discrepancies between text and illustration in the *Kreuterbuch*, and it is likely that these discrepancies can be found with other authors as well.

If we disregard the luting and the recommendations of care in handling the glassware, there does not seem to be any instructions for the best way to set up a furnace to distil. The bath can be preheated or the vessel can be heated along with the sand or water, when the fire burns low it can be replenished with cold coals or with embers, the coolant can be changed when it is lukewarm or when it is hot, and so forth. Some of these questions we can find answers to in other works by other authors, for instance the German physician and herbalist, Valerius Cordus (1515 – 1544) wrote that hot embers should be used (Cordus, 1575, p. 501). Other of these questions remain unanswered.

7.1 The reconstruction of the furnace

In designing and building the furnace a computer program for creating digital three dimensional models, *SketchUp*, was used (figure 7.4). This made it possible to both adjust the design and to easily calculate how much material was needed. It also made it possible to compare different designs with respect to costs and, to some extent, ease of construction. For instance the square design in figure 7.5b would be easier and more cost efficient to build, as no bricks would need to be cut to the trapeze shape needed for a

Figure 7.2: The completed furnace with a cow's reticulum as an improvised moor's head

Source: Source: Nils Kristian Th. Eikeland, NTNU University Library round furnace (figure 7.6), but would contradict Lonicer's recommendation that a round furnace is better than a square one.

Before I continue with the descriptions of the various furnace designs that were evaluated I will first say a few things about the constituent parts of a distillation furnace.

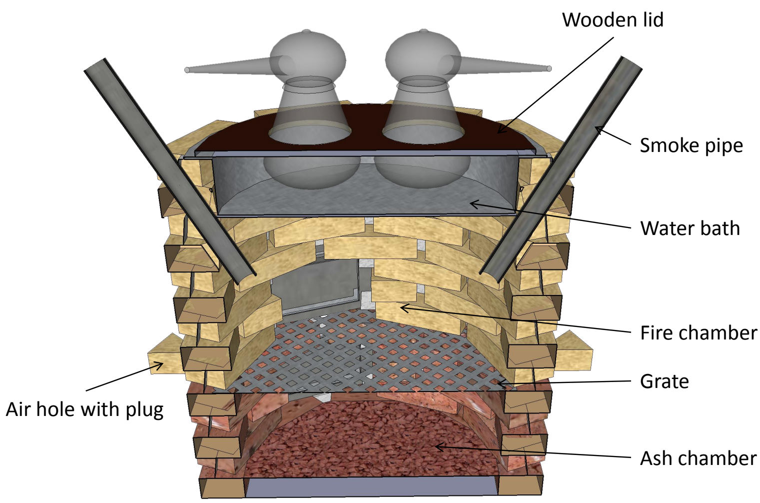


Figure 7.3: A bisected view of a model furnace
Source: F. M. Kirkemo, Exported from *SketchUp*

There are, usually, two larger openings in the furnace. The upper is where the fire is lit and the lower opening is for taking out the ashes. Figure 7.3 shows a bisected view of a furnace. Between the two openings there is a grate or a plate with holes upon which the burning coals lie. This divides the furnace chamber into a fire chamber and an ash chamber. Around the furnace, below this grate are air holes that can be opened and closed with pegs in order to control the air supply and thereby the intensity of the fire. The upper part of the furnace is built to fit snugly around a vat that is filled with water or sand, depending on what type of heat bath that is used. The smoke pipes, or chimneys, always seem to be illustrated as two or more in any one furnace. Lonicer does not specify why this is, nor have I come across any other details of this phenomenon, but may be that this is to keep a more homogenous heat inside the furnace, that is to avoid hot-spots or cool zones in the furnace. Finally the vat is covered with a wooden lid with holes cut out to accommodate the alembics.

As described in section 1.3 the still head is called an alembic, and the beak or tube through which the distillate evacuates the alembic is referred to as a *rostrum* (lat. beak) or sometimes a solen (Forbes, 1970, p. 23). The alembic and cucurbit were, until later in the early modern period, made as two separate pieces (Forbes, 1970, p. 77), that were luted or fused together.

Designing the furnace as a 3D model before construction made it easier to predict any grievances that might occur during the build even before the first brick was laid down. For instance, in evaluating the design shown in figure 7.5a, it was easy to see that the wall of the square base would need to be made from a double layer of bricks. There is no distance the opposing walls of the base can stand and not create a hole between the cylindrical upper chamber and the the lower chamber, or not provide the proper support for the upper chamber.

As can be seen indicated in figure 7.4, the models allowed the exact amount of material needed to be calculated, and the weight of the model can thus be determined. This calculation showed that the weight of the furnace was, with some small margin, less than the capacity of a standard European pallet, allowing for the furnace to be moved after construction.

Several different designs were made with *SketchUp*, two other examples are shown in figure 7.5. The design that was used in the end was the one shown in figure 7.5a.

In the *Kreuterbuch* Lonicer specifies that the furnace should be round in form, at least on the inside. These are "the best and most practical sort of distillation furnace" (Lonicer, 1569, p. 7/fII), though he does not state why they are better than other designs. However in French's (1651) *The Art of Distillation*, French states that round furnaces allows for the best diffusion of heat. However, Cordus states the opposite. According to him it is important that the furnace should be square. (Cordus, 1575, pp. 501–502)

Lonicer writes that the stones for the furnace should be made by creating a template on a wooden board. This is done by drawing a circle as wide as the kettle, and then another one on the outside making the width of the stones 'nach deinem gefallen' (according to your pleasure), like it is illustrated in figure 7.7.

This seems to be a simplified version of a mould described by Hieronimus Brunschwig (1530), where clay or "earth" was stamped together in a wooden mould. This is one of many similarities between these two books. The descriptions of the components of the furnace and the illustrations coincide in so many cases that it seems likely that Brunschwigs *Book of distillation* was a strong influence when Lonicer wrote the *Kreuterbuch*. The illustra-

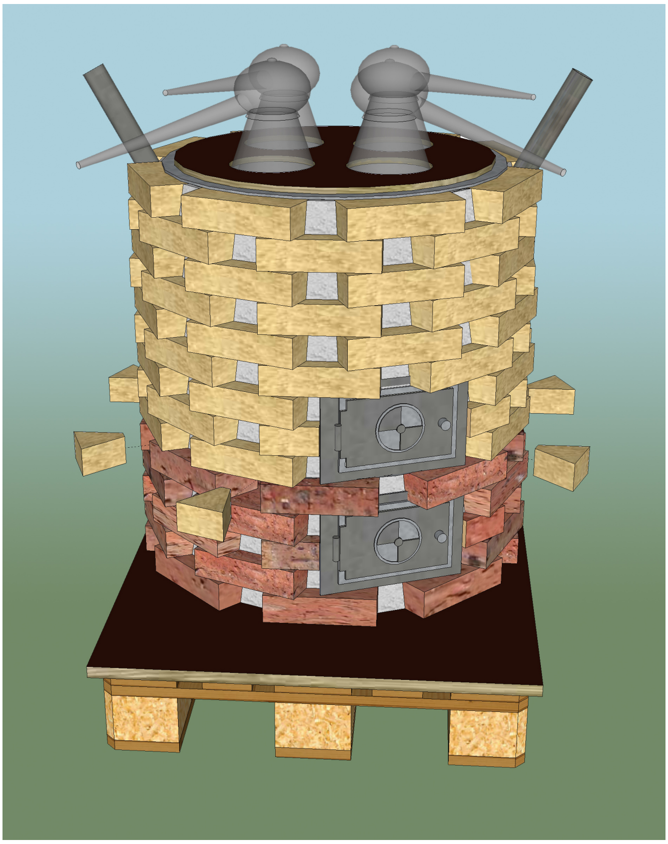
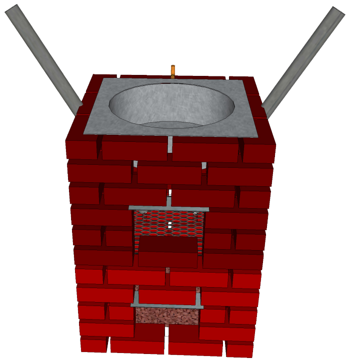


Figure 7.4: 3D model of the furnace made using *SketchUp*
Source: F. M. Kirkemo, Exported from *SketchUp*

(a) The design that was used for the furnace.



(b) A square furnace. Lonicer recommends that furnaces should be round.

Figure 7.5: Different designs made for the furnace.
Source: F. M. Kirkemo, Exported from *SketchUp*

Figure 7.6: Trapeze shaped bricks were made by cutting standard bricks to shape
Source: F. M. Kirkemo

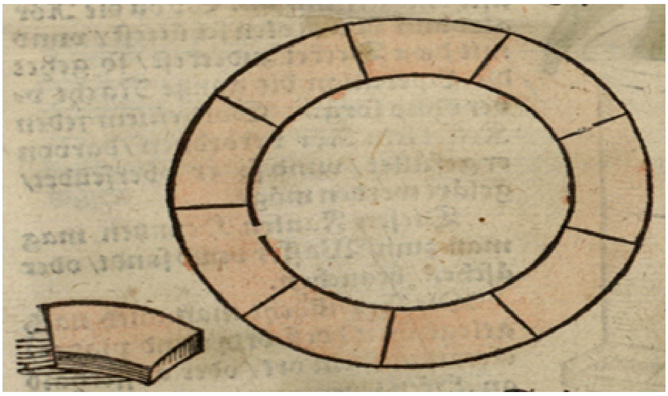


Figure 7.7: "The width of the furnace/according to the width of the kettle/for one or more cucurbits/you draw on a board/in the here-given form"(Lonicer, 1569, p. fIII/9)
Source: Lonicer (1569)

tions in the *Kreuterbuch* are of a better quality than those in the *Book of distillation*, and as a reformist Lonicer has omitted all the "by the grace of almighty god" that Brunschwigs distillation book is riddled with.

As mentioned earlier, Lonicer is sparing with dimensions. He only states that the width of the furnace should be determined from the kettle used for the sand, ash, or waterbath, though he does not give any neither exact nor approximate dimensions for the different furnaces he describes.

As a kettle for my balneum mariae I used the stainless steel tank from a boiler (figure 7.8). This is approximately half a meter in diameter. The exact dimensions of the furnaces does not appear to have been of particular importance to Lonicer. This may be because he, by his own statement, is writing for an audience that are laymen and otherwise unskilled in the finer arts of distillation and chymistry, or he may not have felt that the exact

Figure 7.8: The rim for the kettle is welded on by Robert Karlsen at the University workshop
Source: F. M. Kirkemo

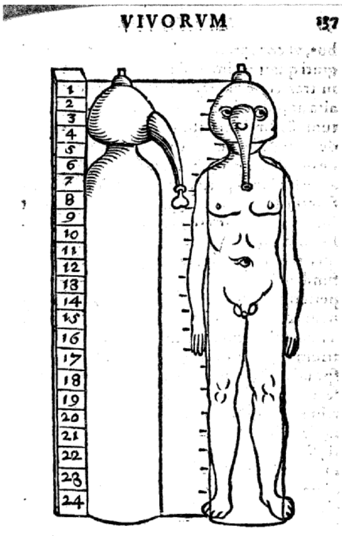


Figure 7.9: Some, although far from all, were very specific on the dimensions of a still. This is from Leonhardt Thurneisser's apparatus for urine distillation, a diagnostic tool ridiculed by it's contemporaries (Schummer et al., 2007, p. 218)

dimensions mattered much since there were so many different shapes and sizes of furnaces anyway.

The English alchemist Thomas Norton (*c.* 1433–*c.* 1513) however did put much store by the size of the furnace (Anderson, 2002, p. 13-14), so there may have been differing opinions on this matter. If the size of the furnace should turn out to be of importance I seem to have been fortunate: Brunschwig writes in his *Book of distillation* that the kettles are "comonly halfe a yarde wyde and depe" (Brunschwig, 1530, p. 11). This means that the kettle I used, and hence the furnace, should be approximately the "comon" size, as Brunschwig calls it. He does not, however, concur with Norton on the importance of dimensions: He continues to write "or more or lesse as it behoueth/accordynge to the proporcyon of the fornayse".

7.2 Reconstruction of Renaissance glassware

The glassware that was reconstructed for the project was made by the university glass-blowers from sketches made from the illustrations in the *Kreuterbuch*. As mentioned, there are ample reasons to distrust illustrations from 16th century distillation books, however the written descriptions were inadequate, so illustrations were used.

The glassware was, for durability reasons, made of borosilicate glass. It was later concluded that this may have affected the reconstruction in that it introduces an unnecessary inaccuracy from the historic artefacts that were reproduced. To fully understand the importance of the composition of glass in distillation apparatuses it is necessary to embark on a discussion of glass from the early modern period.

7.2.1 Glass in the late middle ages and early modern period

At first glance the full extent of the importance of glass in studying chymical and alchemical texts from the 16th century may not be obvious, at least not to every reader. Many of the early stills were made from clay, and was only later commonly made from glass (Rasmussen, 2008), but glass was certainly important to early chemists and alchemists. Even in the medieval laboratories of early chemists and alchemists glass equipment was widespread (Macfarlane and Martin, 2002, p. 43), but the importance of glass is much more profound than this.

I shall therefore try to account for this in a brief section on glass related to chymistry in the medieval and early modern period. We are of course primarily interested in the production of glass equipment for chemical and philosophical purposes, but many sources include the use of glass in a more general sense, such as household purposes. I shall not distinguish between the the two, but in the following it is important to have in mind that I am describing glass from the viewpoint of a historian of Chemistry.

According to Conner (2005, p. 163) glass-makers were among the first practitioners of alchemy among the Greeks, together with dyers, fullers and potters. Glass-makers had their own use of procedures from alchemy and chemistry and of alchemically and chemically produced substances, both in purifying and colouring glass (Neri, 1662; Newman, 2006). It has been suggested that recipe books from craftsmen such as glass-makers was an important route for the transmission of alchemical technological knowledge from the Hellenistic East to western Europe (Eamon, 1994, p. 32).

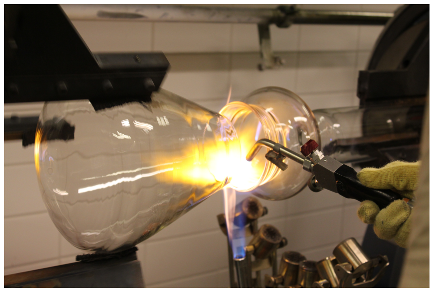


Figure 7.10: The modern glassware was made of modern borosilicate glass Source: Sebastian Bete

The contributions to science from such craftsmen was noted by Francis Bacon (1561–1626), often called the father of empiricism (insert citations). Bacon criticized the sciences of being static, 'like statues, adored and celebrated, but not improved'[1] (de Verulamio , Francis Bacon, p. 3). He called the wisdom of the Greeks a 'boyish kind of knowledge, [...] weak and imma-

[1]Translated by the author. *Philosophia contra, et Scientiæ Intellectuales, statuarum more, adorantur et celebrantur, sed non promouentur.*

ture'[2] (ibid. p. 2). Progress was, according to Bacon, to be found among the arts, and particularly among the mechanical arts. 'They grow and are perfected every day as if they partake of a kind of vital air.'[3] (ibid. p. 3).

To improve and evolve, science and philosophy should learn from the arts and crafts. Bacon specified several and particularly those which "[lift] the mask and veil from natural things" (Bacon et al., 2000, p. 227). These crafts were to be documented in a "Natural and Experimental History, adequate to serve as the basis and foundation of True Philosophy" (ibid. p. 222). Among these we find both chemistry and the manufacture of glass.

The primary sources concerning renaissance glass production are of various natures: Among others there is literature written by glass-makers, like the Florentine chymist Antonio Neri (1576–1614) who wrote *The Art of Glass*; distillation books and herbals with instructions for distillation by chymists and alchemists, like Gesner, Lonicer, Brunschwig and Porta, also contain descriptions, in varying degrees of detail, of the equipment that should be used is an important primary source for our use; there are legal documents concerning the craft of glass-making; and also the archaeological record of glass equipment from the period tell us a lot about the glass they used.

Antonio Neri states that many of the methods used by alchemists and chymists would not have been possible without using glass. Although not much is known about him (Boer and Engle, 2010) Neri writes of himself

[2] *Et de utilitate aperte dicendum est; Sapientiam istam, quam, à Græcis potissimum bausimus, pueritiam quandam, Scientiæ videri, atque habere quod proprium est puerorum; ut ad garriendum prompta, ad generandum inualida et immatura sit.*

[3] In artibus autemmechanicis, contrarium euenire videmus. Quæ, ac si auræ cuisdam vitalis forent participes, quotidie crescunt et perficiuntur;

that he is an accomplished chymist as well as a glass-maker. Like Agricola (1480–1555) and Biringuccio (1480–*c.* 1539) he stresses that everything he writes is by his own experience and experimentation, and not things that have been told him by others:

> [...]in this thing, and in every other matter that I treat of in this present work, the diligent and curious operator shall find, that I have wrote and shown truth, not told me, or perswaded me by any person whatsoever, but wrought and experimented many times with my own hands,
>
> (Neri, 1662, A3-A3v)[4]

His meticulous documentation of his processes is in sharp contrast to many other sources, particularly the manuscripts from the archives of Venice and Murano, that were frequently shrouded in secrecy, to protect the dominance of Venetian glass in the late middle ages and the early modern period. (Beretta, 2009, p. 148)

Neri also states that many of the methods and processes used by chymists would not have been possible without the use of glass. Glass allows for greater freedom and versatility in design than pottery (Rasmussen, 2008), but for the glass to be durable enough to withstand both the temperature

[4]This version of the book, the English translation of 1662, has two separate dedications and three different notes to the reader. Parts of the front matter are numbered by folio numeration prescribed with letters, as opposed to the main matter, which is numbered in common Arabic numerals. To make scrutiny of references easier: page A3 is page 23 and A3v page 24 in the digital version obtainable at `http://www.cmog.org/sites/default/files/collections/A0/A0FE816E-881E-4A1C-B6E1-5EEF695C01AE.pdf`

changes and strong regents used in chymistry and alchemy glass needed to evolve from the soda-lime glass used in the Roman Empire to glass made in Venice and Murano during the 13th through 16th centuries. (Rasmussen, 2012, p 51-59). The Venetian glass contained higher quantities of both lime, magnesia and potash, and less insoluble, non-fusible impurities where the strain from thermal expansion can cause the glass to break. This resulted in glass that could withstand greater heat changes and tougher chemicals (Rasmussen, 2012). Some authors of distillation books, like Brunschwig (1530), even specifies that glassware from Venice or Murano is preferable in performing distillations.

Many factors influence the chemical composition of glass. For instance, if the ash used in the production of glass is made from beech it will contain considerably less quicklime (CaO) than ash made from oak, but more potassium oxide (K_2O), and more than twice the amount of magnesium oxide (MgO, by weight). These differences largely arise from the soil where the trees grow, and so there will be variations within one species as well. Analyses of glass from the Western Roman Empire from the late middle ages show that the different chemical compositions of the glass gave rise to widely varying physical properties, such as melting point, which has been shown to vary from 750°C to more than 1000°C (largely due to variations in the potassium and soda content). (Rasmussen, 2012, pp. 38–39)

A major advantage of the glass-makers of Murano was the exchange of knowledge and technology with the East, particularly the Byzantine glass-makers, and the trade in Syrian ashes, which is of a particularly high quality for glass-making. Combined, among other things, with the existing glass industry in Venice and Murano and the flowering trade with Europe, this resulted in a dominance of Venetian glass that lasted for centuries. (ibid. p. 42–43)

The use of glass to improve chemical apparatuses and equipment gave medieval chemists and alchemists the means to design better ways of cooling still heads. This in its turn lead to improvements in the purity of compounds and solvents produced, especially alcohol.(Rasmussen, 2008) An other effect of the improvements in the glass industry was the evolution of the retort (figure 7.11), an apparatus where the alembic and cucurbit are blown or cast in one piece. (Forbes, 1970, p. 77)

Glass is not solely advantageous in its use in laboratory equipment. Glass is fragile and breaks easily, something noted by Johann Rudolf Glauber (1604–1668) who wrote:

> for ofttimes the care of the fire is committed to heedless servants that break glass instruments by their carelessness.
>
> (Egloff and Lowry, 1930)

Due to its fragile nature glass has to be handled very carefully. Modern borosilicate glass is a lot less fragile than the glass from the early modern period. Even the Murano glass is very fragile, particularly to heat changes compared to borosilicate. The early modern chymists used several more or less successful techniques to avoid shattering the glass when it was heated. Luting and wool cloth were two methods, that Lonicer appears to have favoured. The importance of protecting the glass was so great that lute for glass protection was sold for high prices. Glauber made lute from his own secret recipe that he sold for 200 guilders[5] (Forbes, 1970, p. 178). Others, less successfully, tried to make the glass thicker, thinking that it would withstand the heat better. Because of the thermal insulation properties of glass this in fact makes the temperature difference on the inside and outside of the glass greater, thus increasing the tension in the glass and causing it to shatter more easily.

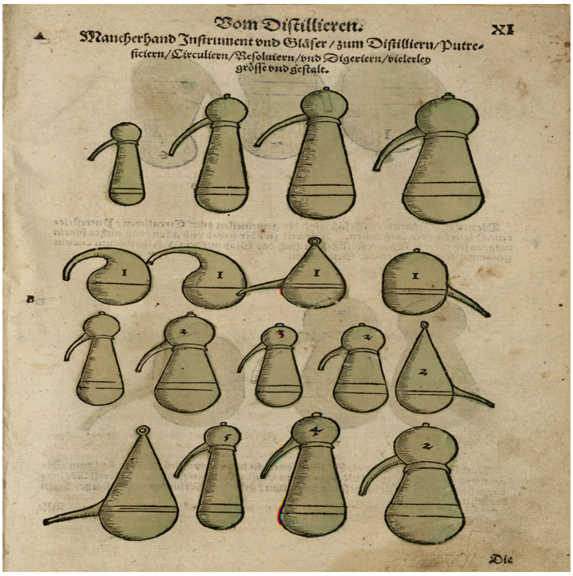
As I will discuss in section 7.5, this all-important task of protecting the glass from shattering is an aspect of 16th century distillation that has not been reconstructed in this project.

7.3 The reconstructed glassware

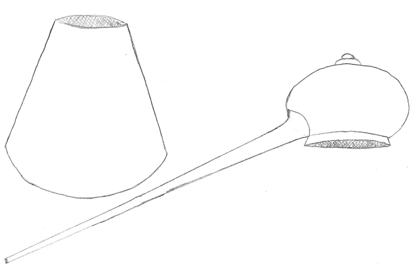
Based on the illustrations on page fXI/23 in *Kreuterbuch* a #2 type cucurbit was selected and the alembic was selected from an illustration that differ from some of the other alembics in that is has a straight rostrum. (Lonicer, 1569, p. IX) This was deemed advantageous since it would ease transport, as the rostrum would be less prone to breakage. A sketch was made for the glassblowers to replicate the pieces of equipment (figure 7.12).

Quite early in the history of distillation alembics evolved to have an inner rim that allows condensed liquid to gather and run out of the rostrum. This allows for more of the condensed liquid to evacuate the alembic, as all of the condensed liquid on the inside of the alembic will gather and evacuate the alembic, as opposed to only the liquid that condenses in the rostrum. (Forbes, 1970, p. 22–23) However during the middle ages the cooling of

[5]According to the International Institute of Social History this is comparable to the purchasing power of € 1770 in 2012 (http://www.iisg.nl/hpw/calculate.php)



(a) Equipment from the *Kreuterbuch*
Source: Lonicer (1569)



(b) Sketch made for the glassblowers
Source: F. M. Kirkemo

(c) The first alembic produced by the glassblowers
Source: Sebastian Bete

Figure 7.12: The alembic was selected from the illustrations in *Kreuterbuch* and reproduced by the NTNU glassblowers
Source: Sebastian Bete

the rostrum became more and more efficient, and the rim eventually disappeared. It did not reappear again until the late middle ages or the beginning of the early modern period. (Forbes, 1970, p. 78)

Figure 7.11: A retort displayed in the Lavoisier Lab at the Deutsches Museum in Munich
Source: Wikimedia Commons, ©Jorge Royan / http://www.royan.com.ar / CC-BY-SA-3.0

This rim is still absent in Lonicer's descriptions and illustrations of distillation equipment. Consequently the sketch that the glass-blowers received did not have any rim. However, the glass-blowers did their own research, and in particular they consulted the Corning Museum of Glass[6], where they learnt of the inner rim that would have been making its way back into the alembics around Lonicer's time. The glass-blowers then altered the design to include such a rim. This turned out to be very fortunate as it later enabled me to compare the distillations on this distillation equipment with the only other reconstructed medieval or early modern distillation apparatus I have come across (this apparatus also contained a rim).

[6] www.cmog.org

At a later stage smaller copies of the first alembic and cucurbit were made to perform small scale experiments in the laboratory. The larger cucurbit measures about 1150 mL when filled to its greatest diameter (when completely full it measures 5500 mL) and the smaller alembics measured about 100–140 mL (530 mL when completely full).

7.4 Distilling with reconstructed equipment

One of the aims of the reconstruction was to evaluate the performance of the reconstructed distillation apparatus. In particular to evaluate to what extent it is possible to make higher concentrations of alcohol with the type of stills that were used in the early modern period. It is a pervasive claim that the advent of the water-cooled alembic had a great impact on the efficiency of stills (Ihde, 1984, pp. 16–17). Should this be the case, then we would expect to see significant differences in alcohol concentrations between distillates made with and without water cooling.

Another point of interest was the effect distillation speed would have on alcohol concentration. A common notion in the early modern period was that distillations should be performed very slowly in order to separate the most subtle spirits or *quinta essentia*. For this purpose very low heat was applied in the distillations. If the distillation speed was an important factor in the efficiency of the still we would also expect to see some difference in alcohol concentrations according to the speed with which the distilland was distilled.

7.4.1 Laboratory set-up

Both Lonicer (1569), Brunschwig (1530) and others recommend 'the best tym and place' (to use Brunschwig's (1530) phrace) for a distillation, depending on the herbal material used. This is often related to when the herbs or plants flower or when berries reach a specific stage of maturity. In many cases the recommended time to distil herbs and plants is in spring or autumn. The outdoor temperature (and to a lesser extent the atmospheric pressure) will affect the performance of a distillation that is carried out out-doors. Particularly the air temperature will affect the cooling of the alembic. As the winter climate in Trondheim is hardly comparable to the spring and autumn climates of continental Europe, and to ensure comparable conditions for every distillation, a laboratory set-up was used for most of the distillations.

A Büchi B-480 waterbath from a rotary evaporator was used to simulate the furnace *balneum mariae*. A jig to secure the cucurbit and alembic was fashioned from a shortened lab.-stand ring and a clamp that was held in place in the waterbath by a second clamp (figure 7.13).

Thermometers were employed to measure the temperatures of the room, the waterbath and the outside of the alembic, or of the cooling water when the alembic was water cooled. For measuring the temperature of the outside of the alembic the metal casing was removed from the probe of a digital thermometer and the probe was fastened to the alembic with tape under a piece of twice folded aluminium foil. Unsurprisingly this turned out to be a rather poor measurement of the distilling temperature, so a second version of the small-scale apparatus was later made with a hole in the alembic wall.

This allowed the distilling temperature to be measured inside the alembic rather than on the outside. In the moor's head distillations an additional thermometer was used to measure the cooling water temperature.

Batches of different concentrations of distilland were made volumetrically from $96\%_{v/v}$ ethanol and calibrated by refractometer (as described below). As each batch was distilled fractions of approximately 4-5 mL were collected, and ethanol content was determined.

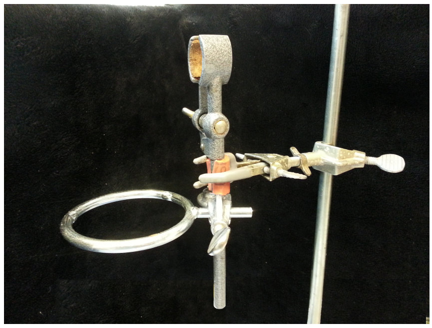


Figure 7.13: The clamp grasps the *rostrum* of the alembic. The jig is held in place by a second clamp
Source: F. M. Kirkemo

7.4.2 Ethanol determination

The determination of ethanol content was done refractometrically using a Reichert AR200 digital hand held refractometer. A calibration curve was made by determining the refractive index of samples of $10\%_{v/v}$, $20\%_{v/v}$, ..., $100\%_{v/v}$ ethanol prepared volumetrically from $100\%_{v/v}$ ethanol and purified water.

The refractive index of ethanol/water mixtures does not give a linear calibration curve, as can be seen in figure 7.14a.

To obtain a linear calibration curve a technique described by Owuama and Ododo (1993) was attempted. They applied the organic dyes methyl blue and crystal violet to obtain a linear response. When used together, the addition of these dyes will create a linear and fairly accurate calibration curve, however when the standard deviation of measurements were taken into account, as shown in the graphs in figure 7.14b, it became apparent that it would in fact be easier and more precise to dilute each sample with an equal amount of water (1:1) to avoid the paraboloid calibration curve.

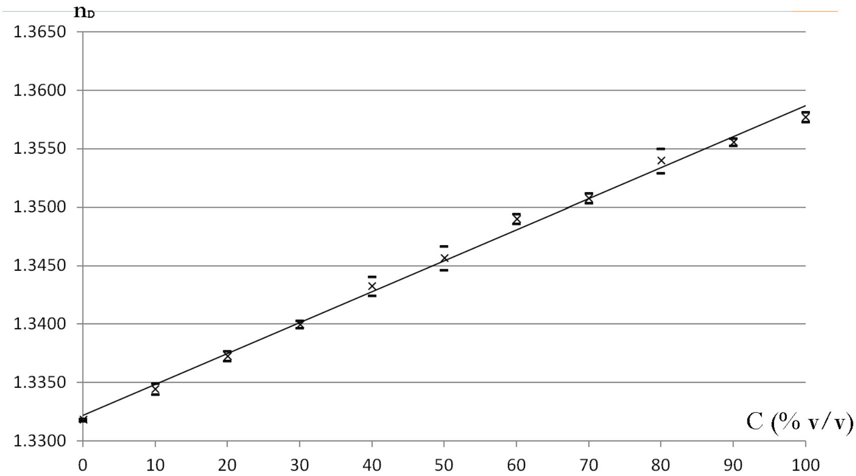
7.4.3 Methods of distilling

To compare the effect of cooling the alembic three different methods of cooling were applied. The first was to air cool the alembic; the second was to use a moor's head (figure 7.15) with a 'static' waterbath cooling the alembic, that is a waterbath where the water is not changed during the distillation[7].

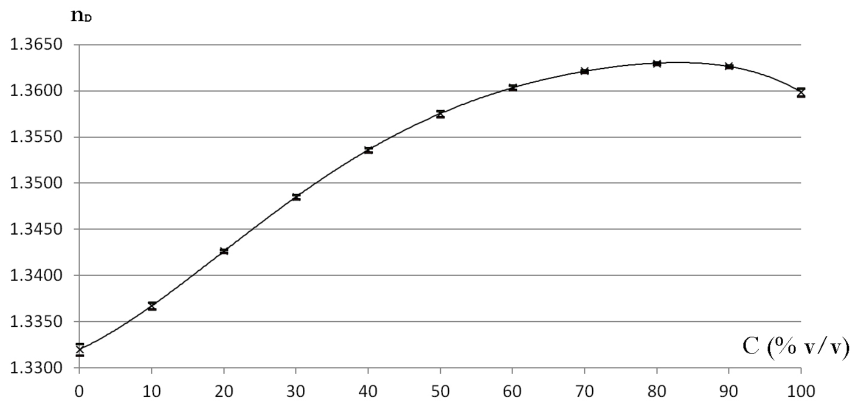
The third and final method for cooling the alembic was an emulation of a method of cooling where the water continually flows through the moor's head from a reservoir. This kind of cooling was described among others by Libavius, as shown in figure 7.16.

In order to save some trouble adapting the moor's head to accommodate a flow of water this was emulated by continually adding ice to the cooling water. This ensured a constant low temperature in the moor's head. It should be noted that the absence of a flow will have had an effect on the effect of the cooling; however the difference between the cooling effect of static cooling with ice water and a flowing coolant was presumed to be relatively small compared to the difference between a static waterbath of around 41°C and an ice cooled waterbath.

[7]It should be noted that it was usually recommended that the water in a static moor's head be changed at regular intervals. Lonicer describes siphons used for the emptying of a moor's head during distillation.



(a) Refractive indexes (n_D) for ethanol/water mixtures of 10-100$\%_{v/v}$ dyed with both methylene blue and crystal violet, as described by Owuama and Ododo (1993)



(b) Refractive indexes (n_D) for pure ethanol/water mixtures of 10-100$\%_{v/v}$.

Figure 7.14: Each point in the graphs is marked by an x with a bar over and under. The x is the average value and the bars represent the standard deviation.

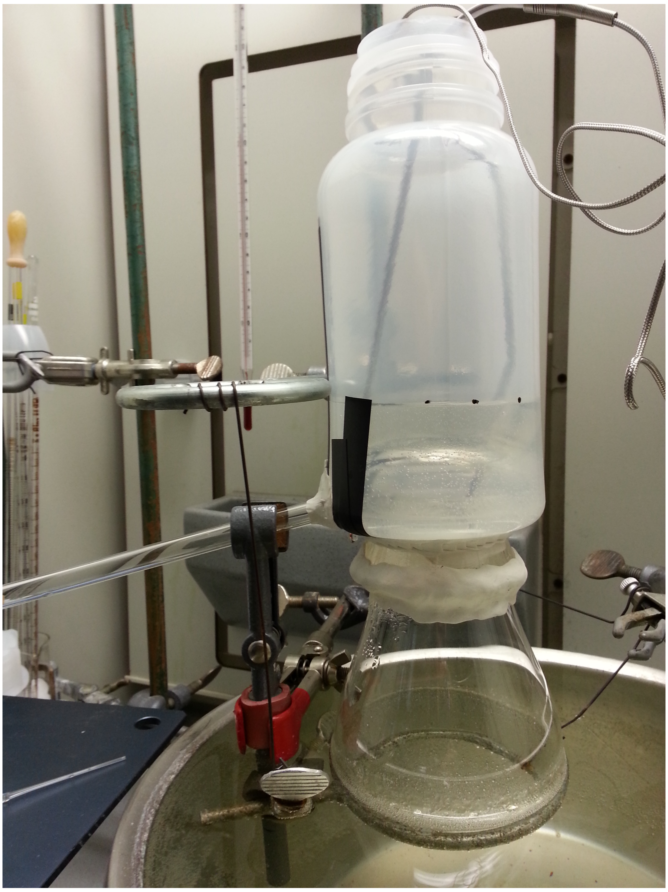


Figure 7.15: Moor's head made from a plastic laboratory flask, 'luted' water proof with Faber Tack-It
Source: F. M. Kirkemo

To compare the effect of distillation speed the waterbath temperature was set to different temperatures to obtain different distillation speeds. A slow distillation, distilling about 28 drops per hour, was obtained with a waterbath temperature of ca. 60 °C, and a (comparatively) fast speed, distilling 200-300 drops per hour, was obtained with a waterbath temperature of ca. 80 °C. The slow distillation distilled just over 30 mL in 14 hours, while the fast distillation distilled the same amount in about 4 hours. All other distillations were run at the same temperature in the waterbath as the fast distillation.

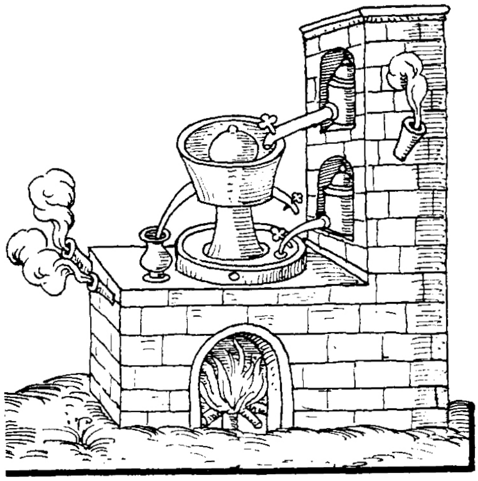


Figure 7.16: Moor's head with flowing water from a reservoir
Source: Libavius (1606)

Most of the distillations used a distilland of 15% v/v ethanol. If nothing else is reported, then this is the distilland concentration. All distillations that are compared to one another have been performed under the all of the same conditions excepting the variable in question.

7.4.4 Results

The first obvious difference observed between the distillations with ice cooling and static cooling was the distillation temperature. As expected an equilibrium between distillation temperature, coolant temperature and water-

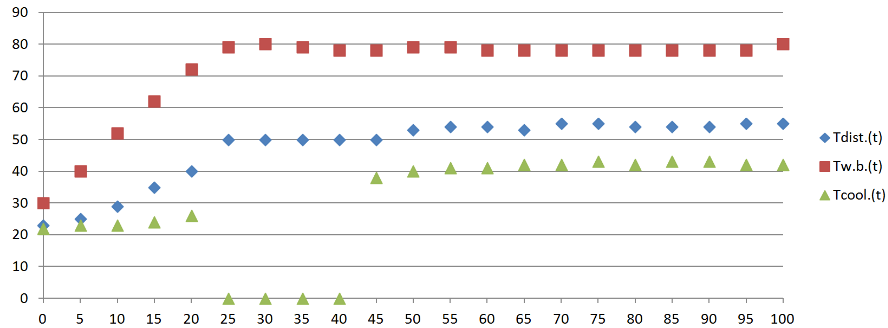


Figure 7.17: Temperatures inside the alembic (Tdist(t)), in the waterbath (Tw.b.(t)) and in the coolant in the moor's head (Tcool.(t)). The time, on the first axis, is given in minutes. (The sensor measuring the waterbath temperature malfunctioned between t = 25 and t = 40 min.)

bath temperature was established after some time (usually 15–25 minutes). Figure 7.17 shows an example of the temperature equilibrium. The time of the establishment of the equilibrium is the approximate time at which ethanol starts to distil.

The coolant in the distillation with ice-water cooling usually measured around 4°C in the coolant. The observed distillation temperature for this distillation, that is the temperature inside the alembic, varied from 40°C to 46°C. As can be seen in figure 7.17, the corresponding values for the distillation with a static moor's head are from 50°C to 55°C. The observed distillation temperature of the air cooled alembic was within 48°C and 51°C. However, when the the ethanol concentrations of the three different distillations are compared there are very little differences between the three. Figure 7.18 shows how the ethanol content of the distillate changed as the distillation progressed. The graph shows the approximate 'instantaneous' ethanol content. That is, the ethanol was determined in samples of 5 mL collected distillate, not in the total amount of distillate.

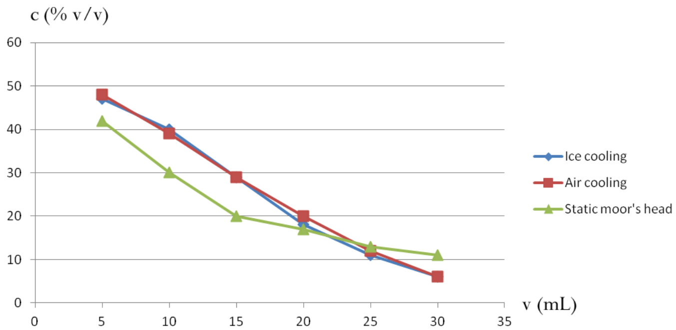


Figure 7.18: A comparison of the ethanol concentrations of the three different cooling methods as the distillations progress

The observed concentrations of the slow distillation show that there is a significant difference in the "instantaneous" ethanol concentration at the start and end of the distillation when the distillation is run slowly. However, these differences are opposite, that is at the beginning of the slow distillation the concentration is considerably lower than in the fast distillation, then the two converge at around 20 mL, and at around 30 mL the concentration in the slow distillation is approximately twice the concentration in the fast distillation.

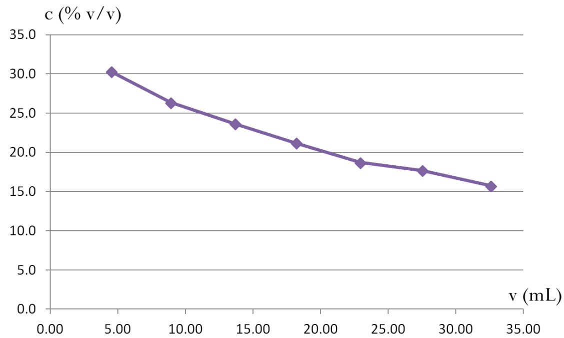


Figure 7.19: Ethanol concentration in the air-cooled, slow distillation

7.5 Conclusions

The laboratory analysis of did not show any significant differences between the various methods of cooling the alembic. The most significant result was that a substantial loss of ethanol was observed when the distillation was carried out at low temperatures. This suggests that the true challenge for medieval distillers when distilling alcohol was not to sufficiently cool the alembic, but their idea that distillations should be carried out at low temperatures (that is to say slowly) and the long pre-heating periods.

The reconstructions, both of the furnace and of the glassware, are made from a combination of illustrations and written descriptions. There are many reasons to distrust illustrations in 16th century herbals and *künstbuchlein*. The illustrations were unscrupulously copied from one work to the next, and were not necessarily made for the work in question; the story of Egenolff and Schott is a conspicuous example of this. We have also seen that there are discrepancies between text and illustration. Non of the illustrations in the *Kreuterbuch* show luted vessels, and yet Lonicer stresses the importance of either luting the vessels or covering them in woollen cloth, tied in place with string.

Certain liberties were taken in the selection of materials, both for the furnace and for the glassware. Modern bricks were used, and the glassware was made from borosilicate rather than glass comparable to Renaissance Murano or Venice glass. This will of course have affected the way the glass was handled, even though every effort was made to treat the glass like it was more fragile, by warming it slowly and so forth. This is arguably a weaknesses with this reconstruction. The genuine feel of the reconstruction is affected, and the borosilicate glass has different heat diffusion properties from other types of glass, which can have a possible affect on the performance of the glassware. It should always be a goal in reconstructions to replicate as much of the conditions of the original process as possible. In the words of professor Lawrence Principe: “you can start by turning off the electric light”. Every smallest deviation from the authentic conditions can have unforeseen consequences for the results. Colours may appear different in electric light, volatiles may be adsorbed on a ceramic surface removing smells, a brass or silver mortar can act as a catalyst where an iron mortar inhibits a reaction, German, Italian and British clays can have different heat capacities, changing the thermal properties of furnaces, and so forth. The possible sources of error are numerous for each deviation from the authentic condition.

Still, the reconstruction of the furnace and glassware did afford several advantages. First and foremost as a way to structure the study of 16th century distillation. When reading a text to copy the instructions in real life a whole new form of attention is given to details that would otherwise have passed unnoticed. The exact workings of each instrument has to be understood, and sometimes it is difficult to understand them before they are made and 'toyed' with. An example is the inconspicuous devise shown in figure 7.20. This proved difficult to understand based on the text alone, an not until a small model was built with perforated metal strips did the purpose of the devise begin to become clear. The devise is for mounting a cucurbit so that the neck will fit snugly into a hole in a lid that can also function as a alembic. In this way two distillations can be performed using the same fire.

Other insights came as the furnace was being used. If the furnace is replenished with coal during distillation the temperature in the burning chamber will fall causing uneven distillation temperatures (this is of course viewed with modern eyes!), however it hot embers were kept by the furnace to replenish the fire the distillation temperature remains more stable. This turned out to be intuitive to the Mubil project leader, Alexandra Angeletaki. She is Greek and this reminded her of how she used to braise meat in Greece. Lonicer does not describe this, but it can be found in more extensive works on distillation, like Cordus (1575, p. 501–502).

The reconstruction was carried out as what Woodman (2009) refers to as a "factual reconstruction", that is the basis for the reconstruction has been texts and illustrations. However there was an element of hypothesis in the reconstruction as well, as several aspects of the furnace were undocumented by Lonicer. One example is the size of the furnace. This was determined from what material we had available, such as the hot water boiler that the waterbath was made from, and what seemed ergonomically reasonable. This

So man diesen Ofen machet / setzet man ein eisen Creutz/ das die vier Wende begreifft/ob den Rost deß Ofens/mit einer vbersich gehenden schrauben/also/wie hieneben verzeichnet ist.

Solche Schraube gehet vnden durch den Hafen/mit eim Schräublin wol angezogen/vnd verlutirt / daß es Wasser halten möge. Darnach thut man das hievnden verzeichnete Instrument oder Refflin/darein das Kolbenglaß verfasset/in den Hafen/Ist von subtilen Eisen/od' Küpfferin Blechlin gemacht/vnden mit einem Mütterlin/in die Schraub gehörig. An den Gleychlin in der mitte hats einen höltzinen Reiff / Die obern blechin ärmlein bindt man oben mit einem Schnürlin zusammen/die das Kolbenglaß satt vnd ställ halten / Solcher Form vnd gestalt/wie du hie vor Augen sihest.

B

Darnach stürtzt man den Deckel darüber/der hat in der mitte ein rund Loch/darein sich deß Kolbenglaß Halß füglich schicket / Treib also das Glaß mit dem Instrument im Schräublin auff oder ab/ biß sichs rechtins Deckels loch schickt/ Alsdann verlutier den Deckel auff den Hafen mit geweichtem Käß/vnd lebendigem Kalck/auff ein Tuch gelegt/vnd darüber geschlagen / so stehet der Ofen also/ wie du hievnden fürgemahlet sihest.

Vnnd so dieser Deckel / dardurch der Alembic gehet/ au ch gemachet ist wie ein Helm / wie hieneben zur lincke Handt verzeichnet stehet / Nemlich/ mit einer Rör oder Schnabel / so mag man zugleich zweyerley mit einander/ als in der Scherben oder Hafen/vnd auch im Kolben / Distillieren/jedertheils vnverhindert.

B ii Ein

Figure 7.20: A devise for mounting a cucurbit in a waterbath
Source: (Lonicer, 1569, p. fVIII/19)

turned out to result in a size that is a good match to descriptions found in other books of distillation.

The idea of tacit knowledge, according to (Polanyi, 2009, p. 4) is that "we can know more than we can tell". This makes it implicitly difficult to express what we learn through tacit knowledge. The act of reconstructing the distillation furnace became to this thesis the central backbone to which association processes would be linked. This affected the structure of the work itself as well as the structure of the written thesis. This is perhaps best seen in how the fragments of distillation history have been scattered through the second part, rather than as one chapter in the first part.

Chapter 8

Educational perspective

8.1 Methods for implementation of history in science teaching

One ‘use’ of history of science often quoted is in education. Thomas Kuhn wrote, in *The Structure of Scientific Revolutions* (1962, p. 15) that the earlier forms of historic records in education have been “a repository for [...] anecdote [and] chronology” (Kuhn, 1962, p. 1), and that “a concept of science drawn from [these historical representations] is no more likely to fit the enterprise that produced them than an image of a national culture drawn from a tourist brochure or a language text”. This kind of historical foundation for the history of science provides the basis of “unhistorical stereotype[s]” (ibid.), on which erroneous conclusions on the content of science may be constructed, including conclusions about scientific methods. How history is presented in science education is important to science itself, because scientists base their understanding of what constitutes a scientific method (partly) on their understanding of its historical foundation.

Kuhn argued that the scientific activity, rather than just the results, from the history of science should emphasized. If we adopt this view, history of science aught, ideally, to be an inseparable part of teaching science, as learning only the theories and contemporary practices in science students will be oblivious to how science has evolved and how science was practised through history.

Nevertheless history in science education should be used with prudence. Douglas Allchin's (1992) of the University of Minnesota warns that "History is not an overarching framework through which science inevitably makes sense". Science students obviously first and foremost need to learn the contemporary science, and the application of other teaching strategies besides the historical approach is appropriate. To argue that one comprehensive teaching strategy can out-preform others is probably just as much a tourist brochure-equivalent with regard to pedagogy (and common sense) as the (traditional) history presentation that Kuhn refers to above. Variation in teaching methods is more important to sustain students' motivation and interest and therefore also understanding than the specific teaching method (Nergård, 2008). No such panacean method of teaching is likely to exist.

Allchin (1992) has made a useful summary of how the history of science can be used to enhance science teaching. He breaks the aims and contexts of historical teaching strategies down to a series of nine "methods":

1. *Celebrating Discoveries and Great Scientists: Exemplifying the Value of Science and Portraying Role Models*

2. *Providing Developmental Themes and Story Lines*
3. *Teaching Process of Science*
4. *Teaching Concepts*
5. *Teaching Process Skills*
6. *Identifying Potential Misconceptions and Ways to Address Them*
7. *Teaching about Conceptual Change*
8. *Showing the "Human" Dimension to Science*
9. *Highlighting the Cultural Basis of Ideas and Research*

(Allchin, 1992)

These nine methods make up a useful tool for an objective oriented planning of curricular resources. I will, briefly, suggest how Adam Lonicer, his Kreuterbuch and the history of distillation may be employed with respect to some of these methods.

As mentioned by several historians of science (Egloff and Lowry, 1930; Taylor, 1945; Forbes, 1970) distillation is one of the earliest and most important chemical technologies. Its history should therefore have a natural place in the teaching of chemistry. However the educational ‘uses’ for the history of both distillation and of Lonicer can also be applied in other science subjects.

8.1.1 Celebrating Discoveries and Great Scientists

An "exclusive emphasis on 'heroes' and dramatic discoveries may be misleading." A black-and-white picture of both 'winners' and 'losers', must be avoided. Instead to "[demystify] their achievements and openly [recognize] their flaws" (Allchin, 1992) woul probably be a preferable route.

Here Adam Lonicer can provide an example of a scientist working within the boundaries of "normal science" (Kuhn, 1962, p. 23). Many of the scientists and discoveries from the history of science that are referred in science education are the scientists and discoveries associated with the paradigm shifts. Since the vast majority of scientists work within "normal science" the role models and vignettes from the history of science should also contain stories of the everyday-scientist. The university mathematician, the court astronomer or the town physician who didn't partake in the "great events" of his field, but who worked within them and exemplifies the "normal science" of that time.

Adam Lonicer's story reflects his double role as a scientist and a publisher. He is an example of a scientists who made a profit of his work – a reminder that this is hardly a new phenomenon. Ulterior motives can also be part of scientists' 'drive'. Making money of it and gaining fame are the most obvious ones. These motives may well threaten the reliability of the scientist's work. Consider for instance a scientist looking to make easy money. He happens to inherit a printing press, so if he has an ample supply of books that he can piece together to a seemingly new work he stands to profit not only from any form of royalties or payments for the work, but also as the publisher of the work. The story of Adam Lonicer and Christian

Egenolff could serve as an introduction to a discussion of plagiarism and the reliability of scientific work.

8.1.2 Providing Developmental Themes and Story Lines

One of the foremost examples of concept development in science teaching, at least in chemistry, is atomism. The illustrations, like the one shown in figure 8.1, of the atomic models of Dalton, J. J. Thompson, Rutherford and Bohr are common in most undergraduate text books in chemistry. Like many of the examples of developmental themes and story lines in education (electromagnetism and genetics are two others), atomism is a theoretically funded development. That is, the theoretical development holds centre stage. The technological or experimental development that often accompanies the theoretical development is often given less attention. There were technological aspects to the development of atomism: The advent of the cathode ray was a prerequisite to J. J. Thompson's atomic model, just as the Geiger-Marsden experiment was to Rutherford's. However it is the development of the *theories* of the composition and structure of the atom that the story line describes, not the scientific activities that led to them.

The history and development of distillation technology could be provide a complementary story line with a stronger emphasis on the activity of science, rather than just the results it has produced, in accordance with Kuhn's criticism of previous use of history in science teaching. As a technology, rather than a theory, distillation is perhaps more closely knit to the practices and activities of science. That is, distillation is something that a scientist may do on a regular basis, while Gibb's phase rule or Henry's law

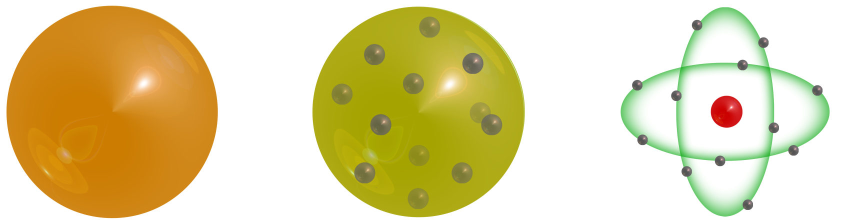


Figure 8.1: The development of the atomic model is a common example of a developmental theme or story line in chemistry education. (Recreation based on Nicholson (n.d., p. 6))

aren't.[1]

Distillation also serves to demonstrate how different technologies can be interrelated and contribute to one-another. The development of distillation technology is, as shown by Rasmussen (2008; 2012), intimately linked to the development of glass-making and propelled forward by its use in both metallurgy and medicine. Distillation represents a link, both historically and contemporary, between crafts such as glass-making and mining

[1]The relationship between science and technology is a subject worthy of its own considerable attention, but for this occasion I will not discuss it any further than saying that the science and technology are intricately interlaced, and the boundaries between them have been disputed (see e.g. Brooks, 1994). I have tried to avoid ambiguity by comparing technology to *theoretical* science. By theoretical science I refer to hypotheses and scientific theories that may rely on experimental evidence, but does not pertain only to experimental procedures or processes. E.g. Henry's law is a theory that applies to all liquid-gas equilibria; it is in that sense 'theoretical science'. Brunschwig's hypothesis that the efficiency of a still is dependent on its height pertains to the functionality of the still, and is as such a technological hypothesis rather than a theoretic scientific hypothesis.

to sciences such as medicine and chemistry. Distillation therefore offers a suitable starting point for discussions on the relationship between science and technology.

Another, perhaps less important reason to discuss the history of distillation is to overcome what appears to be a common misconception today: that distillation as a technique is confined to the organic chemistry laboratory, with little practical use elsewhere. Even the "distilled water" in the student laboratories is often purified by ion exchange filters, not surprisingly this misconception persists. A quick survey of a small sample of undergraduate textbooks in inorganic chemistry[2] shows that distillation is mainly treated as a means to remove water, ammonia and other volatile, often organic, components or to obtain pure gases such as N_2 or O_2 from mixtures. The early alchemists, who were among the foremost users of distillation in the first millennium, were chiefly concerned with metallurgy (Newman, 2006). The "organic" use of distillation didn't start to dominate before the 12th century, with the advent of the distillation of alcohol. The development of distillation technology may serve as a theme for a discussion about why distillation seems to be more frequently used in organic chemistry, and how the apparatuses changed to better tackle the challenges of separating compounds with relatively close boiling points, such as those of water and ethanol.

[2] A small sample was reviewed, mostly by using digitally searchable editions. The books used were Rayner-Canham and Overton (2006), Palmer (1970), Holleman and Wiberg (2001), Wulfsberg (2000), House (2013), Singh (2010), Arora (2005) and Fackler and Falvello (2011)

8.1.3 Teaching concepts and process skills

Allchin (1992) states that "[h]istorical episodes often conveniently model how students may actively (re)construct concepts on their own." The emergence of ideas in science may thus give a structure for students' development of their own understanding of the concepts. Different reconstructed distillation equipment from different stages in the history of distillation can in this manner aid students to develop their conception of distillation, that is their understanding not only of how distillation works and what leads to a better separation, but also what they understand by the concept as a whole.

The simulation of the historical development of distillation as a separation technique may stimulate understand what conceptual and technological resources were needed for distillation to evolve in the way it did. In experimental work emphasis can be given to different elements such as joints, cooling or apparatus height. Students can then discuss the effectiveness of different apparatuses and hopefully this can help them to develop a better understanding of both how distillation technology has advanced, but also what elements are important to successfully separate liquids by distillation.

"Teaching process slkills" is according to Allchin "When students are allowed to recapitulate history in their own development, they also develop the skills of doing science." This method of teaching applied to experimental work, accompanied by class discussions could enable students to gain insights into both the physical and social processes of science.

8.1.4 Highlighting the Cultural Basis of Ideas and Research

The aim of the teaching method Allchin (1992) calles "highlighting the cultural basis of ideas and research" is to apply "the human context of science [...] to highlight its broader social dimensions" . The history of distillation illustrates provides examples of various different interpretations of the "human context of science" such as the influence of culture and society[3] on science and technology and vice versa, as well as the cultural aspect of science as a human enterprise. I will explain and exemplify in the following.

Distillation has been exercised and developed in different cultures: The Hellenistic scholars in Alexandria, the Greeks, the Islamic alchemists and the European chymists all had their own approaches to developing distillation technology based on their own traditions of craft and science, and of documenting their practices.

On the other hand the development of technology can also affect a culture or society. For distillation, excessive drinking followed, ans then edicts to control this appeared all around Europe (Forbes, 1970). This aspect raises the possibility of employing the history of distillation in discussions on science and society and the mutual effect they can have on each other.

To embrace the debate about how distillation, as a chemical technology, has been adopted in certain subcultures where illegal home distillation of

[3]In this context I understand culture the way it is defined in Merriam-Webster (2000) as an anthropological term: "The sum total of the attainments and activities of any specific period, race, or people, including their implements, handicrafts, agriculture, economics, music, art, religious beliefs, traditions, language and story". By the term society I mean the system or structure on-which this culture is built. A sum of sub-structures such as legislative, economical, territorial, political or class structures.

alcohol is practised would not be much of a detour. Virginia and North and South Caroline have become well known after television programs have documented these activities. Trøndelag in central Norway, the area in-which our University is situated, is well known for a widespread culture for home distillation, especially the rural areas. One can safely assume that many of the practitioners of illicit home distillation are unlearned in chemistry, but still they have adopted a chemical technology. Many students from these areas may know of home distilling practices, and may even be able to compare home distilling techniques to historical techniques. More important however (at least to the educator in chemistry), is the fact that the existence of this experience and know-how can be an excellent basis for discussing how the scientific technology, separate from the science, has influenced the culture, and how society and the culture have imposed a situation where the technology has evolved separately from the scientific community.

In addition to the mutual influences between society and science, the cultural basis of ideas and research may also be viewed in light of the scientific culture. That is, to view science as a culture, and see how the scientific view of the history itself can be used to distinguish different scientific cultures.

To use the history of distillation again: There is a problem in determining precisely when and where distillation was first used. This is to a certain extent due to poor documentation of the early practices of distillation. Egenolff was one of the first to print treatises about crafts such as distillation (Eamon, 1994, p. 114). Documentation from Alexandria is scarce because of the many fires that have struck the ancient library. The Chinese, like the ancient Greeks, had no traditions of documenting crafts, and neither do we know of any documentation of early distillation in the

India-Pakistan area, though evidence suggests that the technology may have been present here at an early stage (as discussed in section 5.1 on page 64).

This has given rise to the debate about where distillation first appeared, and whether it has been invented independently several places or only in one place and has since spread out from this place, like Forbes (1970) gives a strong argument for. Archaeologists (Allchin, 1979), ethnographers (Maurizio, 1933), historians with special interests in Chinese history (Gwei-Djen et al., 1972) and European historians of science (Forbes, 1970) all present different, and sometimes conflicting theories and interpretations of the historical evidence. Some believe that distillation has appeared simultaneously several places and others that it has spread from one place. Some think it comes from India others from Greece, China or Egypt.

From this we can clearly see that science is not a uniform set of "truths". Students can use this to discuss the scientists role in and influence on the advancement of science. It would be natural also to discuss reliability and validity in this context. When there are multiple explanations and interpretations of the evidence, how can we go about verifying which hypothesis is most likely to accurately explain a phenomenon? And can this always be done? Is it important to know who has written a scientific paper, or is it sufficient to know that it was written by a scientist? It is likely that not all students will have given very much thought to the different cultures within science, and the history of distillation and the interpretation of this history may be used as a central theme or back-drop for a discussion on this topic.

8.2 Mubil

We have, on several occasions, had the opportunity to make use of both the furnace, equipment and theoretical content of this thesis for disseminations in the Mubil project. The project is, as described in the introduction (section 1.1 on page 1), an effort to disseminate the contents of some of the rare and valuable books in the special collections of the University library.

The furnace, lit and with a full set of glassware commands a powerful presence in an educational setting, and it was natural to include a visit to the furnace when students of any age came to visit the library to take part in the Mubil outreach projects. To show how the furnace and equipment can be used to cover a wide range of educational purposes I have in the following given some descriptions of the outreach projects that have been a part of the Mubil project.

8.2.1 Pilot

There have been two different outreach projects in the Mubil project and they have had slightly different aims. The first project was a pilot to test the digital equipment and to see how students would react to the content and the way it was presented. A school class from lower secondary school was invited to take part in the pilot.

The students were divided into two groups, one starting the visit at the furnace and one in the digital laboratory, and then they switched later in the day.

In the digital laboratory they were set to examine the augmented, digitized version of the Kreuterbuch both on 2D touch screens and on a large

3D screen.

Outside, at the site of the furnace, the students were part in a practical demonstration of both historical and modern distillation. We first described briefly how the furnace was constructed and why it was constructed in this manner. Then the students were shown the equipment and materials needed to perform a distillation.

This included ingredients for making *luteum sapience*: flour, egg white, animal hair (kindly lent us from my supervisor's cat), clay, horse manure etc. For cooling we demonstrated how the reticulum from a cow[4] could be used to make a moor's head. The animal components awarded strong reactions from the students both of fascination and disgust.

We then proceeded to make an ethanol extract of juniper berries that we set to distil in the furnace. In his recipe for "juniper berry water" (Lonicer, 1569, pp. 81-83/XL-XLI) Lonicer does not specify the use of extraction. We do however know that he has described a form of extract distillation:

> [...] distil mixtures / that is / herbs to which wine or vinegar has been added.
>
> (Lonicer, 1569, p. fVIIIv)

We chose to distil an ethanol extract (approx. $50\%_{v/v}$) from juniper berries for several reasons. First of all adding a volatile compound means that the mixture will start to distil visible amounts of distillate quicker. This we deemed to be advantageous since it would lessen the chance of students

[4]Lonicer prescribes a bladder, but for health and safety-reasons we decided to use a reticulum instead.

losing patience waiting for the distillate to distil over to the recepium. It would also increase the amount of distillate produced compared to a dry distillation of only crushed berries. This makes it easier for the students to compare the two liquids, distilland and distillate, and see that the distillate is clear and colourless while the distilland is cloudy and dark green or brown in colour.

These effects could also have been achieved by adding wine to the berries. The use of wine would however make it more difficult to see that compounds from the juniper berries were extracted into the liquid, and this gave us the possibility of talking about extraction as a means of separating mixtures and stress the fact that distillation is one of several techniques for separation in chemistry. The use of ethanol also made it possible to increase the amount of the volatile component, ethanol, in the solvent without altering the students' perception of the solvent. Most students will be familiar with alcohol of different concentrations, and still perceive them as alcohol; "spiking" wine by adding more ethanol to it may alter the students perception of the wine. Even though the wine has alcohol in it some students may perceive the solvent as wine *and* alcohol, rather than as one solvent. The use of ethanol (approx. $50\%_{v/v}$) would in our opinion lessen any such problems.

The final reason why the choice of ethanol is advantageous is that it enabled us to talk about quantitative analysis. The distillate contains a higher fraction of ethanol than the distilland, but will the students have given any thought as to how we know how much of the liquid is alcohol and how much is water? Most students will be well acquainted with the fact that chemists are able to perform analyses of chemical compounds, substances, liquids or gases from television shows with scientific or quasi-scientific content. These forms of analysis were not available to the Renaissance chemists, and this will not come as a surprise to the students, but how did they then distinguish different concentrations of ethanol[5] from one another?

The students quickly suggested tasting as a means of determining alcoholic content. This lead to a discussion of how accurate taste can be as a tool for chemical analysis. We then talked about what characteristics of alcohol and water mixtures would be easy to test without any instruments for analysis. Alcohol burns, but water doesn't, so at some point a mixture of alcohol and water would stop being combustible if you add water.

After having talked about this I told them of the analysis described by Forbes (1970, pp. 67-68, 89 and 129) from several different sources, where a piece of cloth is soaked in the distillate and then set fire to. A concentration of around $30\%_{v/v}$ ethanol represents an approximate greatest lower bound for the flammability of ethanol and water mixtures, and the heat from the combustion of the ethanol in the mixture will evaporate all the water at a concentration around $60\%_{v/v}$. This makes it possible to make a very rough estimate of the ethanol content of the solution.

The concept of measuring alcoholic content by percentage of volume is of course a much more recent innovation, and would not resonate well with the Medieval and Renaissance understanding of aqua ardens. Ortholanus, a 14th century alchemist[6], wrote "If the cloth is not reduced to ashes, this

[5]We did of course stress that at the time of Adam Lonicer and his contemporaries the term "ethanol" or even "alcohol" were not yet in use. Different concentrations of alcohol would have been thought of as different qualities of *aqua ardens* or aqua vitae (or any number of other terms used).

[6]His identity is disputed (Ferguson, 2002, pp. 157-158), but Forbes (1970, p. 67) suggests he may be identical to Guillaume d'Ortolan, who was bishop of Rodez from

is because of the phlegm which preserves it." (Forbes, 1970, p. 67) Our interpretation of the results from the burning cloth will therefore be quite different from the interpretations of alchemists and early chemists.

However the reconstruction did, in this way, provide a setting for discussing not only distillation as a separation technique, but also the need for analyses that can tell us how well a mixture is separated. In later disseminations with older students we also discussed the use of detectors and other analyses in separation techniques at this point.

The students were invited to help crush the juniper berries with a mortar and pestle and mix the berries with alcohol. Other students shuffled coal into the furnace and set the cucurbit in the waterbath.

While we were waiting for the distillation on the furnace we drew the students' attention towards a table where we had set up two different modern distillation apparatuses, one simple and one fractional distillation. We invited the students to compare the modern and the historical apparatuses. We talked about what parts of the apparatuses had evolved and how.

We then discussed the differences between the two modern apparatuses. The students were asked which one they thought was more effective. None of the students present dared commit to a guess, but after I explained in simple terms the principles underlying fractional distillation all the students agreed that this was the more effective separation technique.

To prove this point the distillations were performed at high temperatures distilling black currant squash. The simple distillation was carried out without a splash head, so parts of the distilland would boil over to the distillate. The students compared the colour of the distillates from the simple

1397 to 1417.

and the fractional distillation apparatuses and concluded that a very slight pinkish tint could be observed in the distillate from the simple distillation. They were also invited to use disposable pipettes to taste the two distillates and some students claimed they could identify a very weak taste from the squash in the distillate from the simple distillation.

Chapter 9

Conclusions

In the experimental analysis of the reconstructed glassware there were not found any evidence to support the hypotheses that the development of advanced cooling techniques was instrumental in the advancement in distillation. Forbes (1970, p. 89) writes that "The reason of the late discovery of alcohol was of course partly due to inefficient cooling and the unnecessarily long pre-heating period".Forbes (1970, p. 89) attributes the first success of the distillation of alcohol in Salerno to "the addition of such substances as salt, tartar (potassium carbonate), etc. which absorbed part of the water". It would be desirable to test this hypothesis experimentally as well.

The advantages to reconstructions seem to be two-fold. On one side tacit knowledge related to the reconstruction is personal. The experimenter performing a reconstructed experiment will gain a more personal knowledge that will lead to a different form of reflection than a more 'distant' approach to knowledge, such as a pure literary study (Polanyi, 2009). This tacit dimension of reconstructions has been stressed by several authors, and its value should not be underestimated.

On the other hand reconstructions may lead to counter-intuitive or non-obvious conclusions that are hard (though not necessarily impossible) to come by through other means. Attention can be brought to details that can otherwise easily be lost, such as for instance determining the 'quality' of the product of a distillation. When in-hand it is easy to see that there are great differences between 30% v/v and 60% v/v alcohol. The stronger the concentration the more oily is the feel of the alcohol when rubbed between the fingers, and air bubbles form much more easily in the higher concentration. The reason for building a round furnace may seem strange in a world where bricks are always square, but considering how much easier it is to construct a round vat for a waterbath it is obviously much easier to mould the bricks to fit the vat.

In the present work I have made a case study of reconstruction as a methodology in history of chemistry. As such it is natural to indicate how this methodology could be applied to further expand the knowledge of distillation in the 16th century.

Rasmussen (2008) has suggested that "the poor heat transmission of the [*luteum sapiens* may have made] it difficult to distill volatile liquids such as alcohol". This does however not seem to have been experimentally documented. The thermal properties of different recipes of *luteum sapiens* may have have had different effects on heat transmission, and the effect of this transmission on the ability to distil alcohol does not seem to have been experimentally investigated. It is known that the recipes of *luteum sapiens* were closely guarded secrets, and preprepared lute was sold for high sums of money (Forbes, 1970). If at all possible it would perhaps give some indications on the desired properties of lute if the thermal properties, hardness and other properties of these lutes were to be subjected to experimental research.

I will conclude this thesis with the following quote from Tara Nummedal (2011):

> [...]recent work has demonstrated what most alchemists shared – namely, a penchant for reading, writing, making, and doing, all at the same time. Any history of early modern alchemy, therefore, must attend to all of these practices, as well as the interplay among them.

Appendices

Appendix A

Risk assesment (Risikovurdering)

The following risk assessment was performed during the planing of the distillation furnace, in accordance with NTNU regulations (NT-fakultetet, 2013). The risk assessment was written and submitted in Norwegian, according to standardized forms provided by NTNU.

Enhet: Institutt for kjemi, Vitenskapsmuseet, Gunnerusbiblioteket **Dato: 28.09.12**

Deltakere ved kartleggingen (m/ funksjon): Fredrik Motland Kirkemo (student), Lise Kvittingen (veileder), Renate Kvernberg Bardal (HMS-koordinator, Vitenskapsmuseet)

Kort beskrivelse av hovedaktivitet/hovedprosess: Rekonstruksjon av destillasjonsovn fra 1500-tallet

ID nr.	Aktivitet/prosess	Ansvarlig	Eksisterende dokumentasjon	Eksisterende sikringstiltak	Lov, forskrift o.l.	Kommentar
1	Bygging av destillasjonsovn	Fredrik Motland Kirkemo				
2	Bruka av destillasjonsovn uten publikum	Fredrik Motland Kirkemo				
3	Bruk av destillasjonsovn med publikum	Fredrik Motland Kirkemo				

Enhet: **Institutt for kjemi, Vitenskapsmuseet (seksjon for formidling), Gunnerusbiblioteket** **Dato: 18.10.2012**
Linjeleder: **hhv. Marie-Laure Olivier, Morten Steffensen , Stein Olle Johansen**
Deltakere ved risikovurderingen (m/ funksjon): Fredrik M. Kirkemo (student), Lise Kvittingen (veileder),

ID nr	Aktivitet fra kartleggings-skjemaet	Mulig uønsket hendelse/ belastning	Vurdering av sannsyn-lighet	Vurdering av konsekvens:				Risiko-verdi	Kommentarer/status Forslag til tiltak
			(1-5)	Menneske (A-E)	Ytre miljø (A-E)	Øk/ materiell (A-E)	Om-dømme (A-E)		
1.1	Bygging av destillasjonsovn.	Forbrenning ved sveis av metallkar	1	C	A	A	B	C1	Utføres av fagfolk, for eksempel ved Verkstedsavdelingen ved NT-fakultetet.
1.2	Bygging av destillasjonsovn.	Etseskader ved manuell behandling av basisk mørtel.	1	A	A	A	A	A1	Bruk av hansker ved muring av ovn.
1.3	Bygging av destillasjonsovn.	Personskade eller skade på omgivelser som følge av sprut ved skjæring av stein.	2	B	A	B	A	B2	Arbeid i stor avstand til brennbart og/eller knuselig materiale. Bruk personlig verneutstyr.
1.4	Bygging av destillasjonsovn.	Personskade ved håndtering av byggmaterialer (stein)	2	A	A	A	A	A2	Vurder bruk av vernesko under byggingen.
2.1	Bruk av destillasjonsovn uten publikum	Forbrenning på varme pipeløp	3	A	A	A	A	A3	Vurder behov for isolering av pipeløp.
2.2	Bruk av destillasjonsovn uten publikum	Brannskader fra varm væske fra kolber eller vannbad.	3	B	A	A	B	B3	Vurder behov for å integrere lab.stativ i konstruksjonen for fastmontering av utstyr.
2.3	Bruk av destillasjonsovn uten publikum	Spredning av gnister eller ild til omgivelser eller klær.	1	B	B	B	B	B1	Utplassering av brannapparat og brannteppe. Ovnen plasseres lengst mulig bort fra bygninger. Personlig tilstedeværelse og oppsyn med ovnen under all drift av ovnen.

MATRISE FOR RISIKOVURDERINGER ved NTNU

KONSEKVENS	Svært alvorlig	E1	E2	E3	E4	E5
	Alvorlig	D1	D2	D3	D4	D5
	Moderat	C1	C2	C3	C4	C5
	Liten	B1	B2	B3	B4	B5
	Svært liten	A1	A2	A3	A4	A5
		Svært liten	Liten	Middels	Stor	Svært stor
		SANNSYNLIGHET				

Prinsipp over akseptkriterium. Forklaring av fargene som er brukt i risikomatrisen.

Farge	Beskrivelse
Rød	Uakseptabel risiko. Tiltak skal gjennomføres for å redusere risikoen.
Gul	Vurderingsområde. Tiltak skal vurderes.
Grønn	Akseptabel risiko. Tiltak kan vurderes ut fra andre hensyn.

Appendix B

Safe job analysis (Sikker jobb-analyse – SJA)

According to NTNU regulations, when a risk assessment has been performed, all minor operations should be analysed in a safe job analysis (SJA) (NTNU HMS, 2014). NTNU provides standardized forms for these analyses. The following SJA was performed before the analyses of samples of binary mixtures, distilled with the reconstructed glassware. The SJA was written and submitted in Norwegian.

SJA tittel: Refraktometrisk bestemmelse av etanol i binære blandinger med vann	
Dato: 14.2.2013	Sted: Realfagsbygget, D2-143
Kryss av for utfylt sjekkliste:	

Deltakere: Fredrik Moland Kirkemo (FMK)		
SJA-ansvarlig: FMK		

Arbeidsbeskrivelse: (Hva og hvordan?)

Diverse etanol-vann-løsninger skal analyseres for alkoholinnhold ved refraktometri.

Risiko forbundet med arbeidet:
(Kjemikaliets faremomenter,- se Sikkerhetsdatablad punkt 2 og 7 for veiledning)

R1: Skader forbundet med knusing av glassutstyr
R2: Etanol irriterer hud og øyne ved kontakt.

Beskyttelse/sikring: (HMS faktorer, se neste side)
(Se Sikkerhetsdatablad punkt 8 for veiledning)

S1R1: Alt knust utstyr feies opp med en gang og deponeres i glassavfallsbeholder. Bruk hansker.
S1R2: Ved hudkontakt skyll godt med vann
S2R2: Ved øyekontakt skyll med rikelig med vann i minst 15 minutter eller til legehjelp.
S3R2: Bruk vernebriller

Avfallshåndtering: (Se Sikkerhetsdatablad punkt 13 for veiledning)

Avfall kan skylles ut i vasken.

Konklusjon/kommentar:

Arbeidet utføres med bruk av vernebriller. Hansker når nødvendig. Minimer bruk av løsningsmidler utenfor avtrekksskap. Ved lukt av løsningsmidler i rommet eller søl av kjemikalier skal arbeidet avbrytes mens rommet luftes ut.

Anbefaling/godkjenning:	**Dato/Signatur:**	**Anbefaling/godkjenning:**	**Dato/Signatur:**
Person som utfører SJA:		Romansvarlig:	
		Veileder:	

HMS aspekt	**Ja**	**Nei**	**Ikke aktuelt**	**Kommentar / tiltak**	**Ansv.**
Dokumentasjon, erfaring, kompetanse					
Er det utført en skriftlig risikovurdering av aktivitet/ laben? Noter dato	X				
Lignende arbeidsoperasjon/oppgave?	X				
Kunnskap om erfaringer/uønskede hendelser fra tilsvarende operasjoner/oppgaver? – spør veileder	X				
Har du mottatt opplæring av apparatur/instrument ansvarlig? Noter dato	X				
Kommunikasjon og koordinering					
Håndtering av en evnt. hendelse (alarm, evakuering)?			X		
Krav til ytterlig veiledning/ Jobb-alene-alarm?		X			
Arbeidsstedet					
Er arbeidsplassen ryddig og velordnet?	X				
Verneutstyr i henhold til NTNU's Lab- og verksted håndbok?	X				
Belysning, ventilasjon/avtrekk?	X				
Bruk av heis/seler/stropper?			X		
Ioniserende stråling?		X			
Rømningsveier OK?	X				
Kjemiske farer					
Bruk av helseskadelige/giftige/etsende kjemikalier/gasser?	X			Metanol brukes til å vaske instrumentet. Vurder bytting til aceton.	
Bruk av brannfarlige eller eksplosjonsfarlige kjemikalier/ gasser?				Metanol (evt. Aceton) og etanol er brannfarlige løsningsmidler.	
Er substitusjon av kjemikaliet vurdert?	X			Vurderer om aceton er egnet som substitutt for metanol	
Kjemikaliet/ gass registrert i EcoOnline?	X				
Biologisk materiale?		X			
Støv/asbest?		X			
Mekaniske farer					
Stabilitet/styrke/spenning?			X		
Klem/kutt/slag?		X			
Støy/trykk/temperatur?		X			
Behov for spesialverktøy?		X		Med unntak av refraktometer, som ansees som svært lite risikofylt.	
Elektriske farer					
Strøm/spenning/over 1000V?		X			
Støt/krypstrøm?			X		
Tap av strømtilførsel?			X		
Området					

Behov for befaring?		X			
Merking/skilting/avsperring?	X			Lab.en er merket i henhold til interne retningslinjer.	
Miljømessige konsekvenser?		X			
Annet					

Appendix C

Abstract from ICHC

The following abstract was submitted and accepted for an oral presentation on the *9th International Conference for the History of Chemistry* in Uppsala, Sweden, 21–24.08.2013.

Reconstructing 16th century distillation

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This is a story describing the construction and use of a distilling furnace as described and depicted in a 1569 edition of *Kreuterbuch*[1], published by the German physician and botanist, Adam Lonicer (1528-1586). Our reconstruction is part of the interdisciplinary MUBIL (Museum and Library – a digital laboratory) project.[2]

Lonicer's *Kreuterbuch* is a lavishly illustrated herbal, in which distillation is a central theme. Considering the early Western European history of distillation and the fact that distillation has been, and still is, at the heart of both alchemy and chemistry, a full-scale reconstruction of distillation processes from the 16th century is, in our opinion, an interesting endeavour. With the aid of specialized craftsmen and -women from the University's workshop we were able not only to reconstruct the furnace, but also the equipment and glassware needed to reproduce the distillation techniques of the Renaissance. In addition to investigate the equipment and techniques' efficiency with some modern methods, we had ample opportunity to experience the synergetic effect of working with texts in parallel with the actual reconstruction. The methodology of reconstructing historical equipment and experiments in alchemy and chemistry has showed promise in several studies in history of science[3]. As Martinón-Torres has pointed out[4], there is "a slant in practice-oriented studies towards the metallurgical aspects of alchemy that leaves much room for research on the practical aspects of iatrochemistry". Robert Anderson has clearly demonstrated[5] that the archaeological record of historical distillation has a great potential in complementing the written records. In our humble opinion, the form of reconstruction we describe here could also have a place in the further study of distillation in the history of chemistry and alchemy.

References

1. A digital version is available at http://www.ntnu.no/ub/spesialsamlingene/ebok/kreuterbuch.html
2. For more information see http://www.ntnu.no/ub/omubit/bibliotekene/gunnerus/mubil
3. Essays in Holmes, F. L. and Levere, T. H. 2002. *Instruments and Experimentation in the History of Chemistry.* The MIT Press, London.
4. Martinón-Torres, M. 2011. Some Recent Developments in the Historiography of Alchemy. *Ambix* **58** (3). pp 215–37
5. Anderson, R. G. W. The Archaeology of Alchemy. In Holmes and Levere (*Op. Cit.*)

Appendix D

The Canon's Yeoman's Tale in the original Middle English

This is the original, Middle English version of the excerpt of Geoffrey Chaucer's *The Canon's Yeaoman's Tale*, or *The Canons Yeman's Tale* as it is called in Middle English.

754 *What sholde I tellen ech proporcion proportion*
755 *Of thynges whiche that we werche upon –*
756 *As on fyve or sixe ounces, may wel be,*
757 *Of silver, or som oother quantitee –*
758 *And bisye me to telle yow the names*
759 *Of orpyment, brent bones, iren squames,*
760 *That into poudre grounden been ful smal;*
761 *And in an erthen pot how put is al,*
762 *And salt yput in, and also papeer,*

Biforn thise poudres that I speke of heer;
And wel ycovered with a lampe of glas;
And of muche oother thyng which that ther was;
And of the pot and glasses enlutyng
That of the eyr myghte passe out nothyng;
And of the esy fir, and smart also,
Which that was maad, and of the care and wo
That we hadde in oure matires sublymyng,
And in amalgamyng and calcenyng
Of quyksilver, yclept mercurie crude?
For alle oure sleightes we kan nat conclude.
Oure orpyment and sublymed mercurie,
Oure grounden litarge eek on the porfurie,
Of ech of thise of ounces a certeyn –
Noght helpeth us; oure labour is in veyn.
Ne eek oure spirites ascencioun,
Ne oure materes that lyen al fix adoun,
Mowe in oure werkyng no thyng us availle,
For lost is al oure labour and travaille;

(Benson and Chaucer, 1987)

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