RePoSS: Research Publications on Science Studies

RePoSS #44:

Textbooks and Knowledge Infrastructures of Copenhagen chemistry, c. 1820-1850

Marcus Lee Naldal

August 2018

Centre for Science Studies, University of Aarhus, Denmark
Research group: History and philosophy of science

Please cite this work as:

Marcus Lee Naldal (2018). *Textbooks and Knowledge Infrastructures of Copenhagen chemistry, c. 1820-1850*. RePoSS: Research Publications on Science Studies 44. Aarhus: Centre for Science Studies, University of Aarhus. URL: http://www.css.au.dk/reposs.

AARHUS UNIVERSITY

Textbooks and Knowledge Infrastructures of Copenhagen Chemistry c.1820-1850

Master's Thesis

Centre for Science Studies, Aarhus University

Marcus Lee Naldal
Matriculation number: 2013 07843

Handed in: 15th of June 2018
Supervisor: Kristian Hvidtfelt Nielsen

Table of Contents

Acknowledgements

I would like to thank my supervisor, Kristian H. Nielsen, for reading large parts of my thesis and providing valuable criticism and feedback. He has provided suggestions on writing style, arguments, theoretical points, and reflections which I believe have greatly improved the exposition and the argument.

I would also like to thank Nanna Hedeager-Schelde for reading entire sections, suggesting changes, and addressing some obscure arguments. Likewise, my introduction has improved considerably following a careful reading by Niels Jessen-Hansen.

Regarding the process of writing, editing, and discussing arguments, I especially have to thank Thea K. Tukjær, who have supported my work throughout the process. She has helped me and improved my work enormously while writing and finishing her own master's thesis.

Finally, a more practical note. I would also like to thank my family and friends in Copenhagen who have accommodated me when I studied manuscripts at the Royal Library. Likewise, an anonymous thanks to the helpful librarians, archivists, and others who I have encountered during my work.

Marcus Lee Naldal, 2018

Abstract

This master's thesis discusses the role and functions of textbooks in *knowledge infrastructures*. My thesis introduces the distinction between *indicators* and *factors* from conceptual history to textbooks and textbook studies. It is argued that there exists a tradition which mainly considers textbooks as indicative instead of being both.

My master's thesis has two main parts consisting of a number of subsections. The first main part is concerned with providing an overview of previous historiography and suggesting new approaches. I present my arguments for the existence of an indicative tradition of textbook studies, and I present a reevaluation of textbooks in studies from the 2000s.

In order to conceive textbooks as active I employ P.N. Edwards' notion of knowledge infrastructures. Knowledge infrastructures expand the list of elements participating in networks beyond the social to include identities, norms, and physical elements like the textbook. Knowledge infrastructures provide a framework for seeing textbooks as active. I argue that textbooks may serve as infrastructural elements or actively manipulate knowledge infrastructures. I also present some theoretical arguments for analyzing textbooks as part of knowledge infrastructures, e.g. the concepts of *gateways* and *entry points*.

The second main part is to substantiate my theoretical argument. In three empirical analyses I analyze textbooks written and translated by three Danish chemists during the early establishment of chemistry at the university of Copenhagen and the Polytechnic College. I analyze how textbooks were used to demarcate chemistry as a discipline, how textbooks discussed atomism, and finally how textbooks could function in relation to the practical training of chemists.

This master's thesis argues that textbooks are indicator-factors. They have been used by actors to assert identities, form new generations of practitioners, and to standardize actions. Furthermore, it argues that a viable way of studying this is through the vocabulary of knowledge infrastructures.

Textbooks and Knowledge Infrastructures of Copenhagen chemistry, c.1820-1850

Introduction

The textbooks will have to be rewritten! This is an eye-catching description used to invoke our curiosity in printed and online media. Some recent examples in Denmark would be articles from the online site for science communication *Videnskab.dk*, e.g. (Lauritsen, 2017; Sjøgren, 2018). Both instances tap into our common notion of textbooks as repositories of accepted knowledge. When unexpected knowledge arrives, e.g. that our general classification of dinosaurs into two main groups may have been wrong all along (Lauritsen, 2017), our accepted knowledge may shift and our textbooks rewritten.

The widespread understanding of textbooks as repositories of accepted knowledge is indicated in a recent committee report published by the Danish Ministry of Higher Education and Science. At the same time, the committee report also challenges this common understanding. The committee report recommends that universities should acknowledge the value of writing textbooks and further suggests meriting textbooks as research if they include contributions to research (Udvalg om bedre universitetsuddannelser, 2018: 10). That universities do not acknowledge the merits of textbook writing may have various causes but a central reason could be our understanding of textbooks as expository repositories in contrast to the creative science pushing the frontiers of science (García-Belmar et al., 2005: 219-220). However, the committee suggests that textbooks may actually contain contributions to research and from a historical point of view this is almost an obvious possibility. In the nineteenth century, for instance, it was expected that textbooks included recent discoveries which required a lot of work from textbook writers like the Danish chemist (among other occupations) H.C. Ørsted (1777-1851) or the Swedish chemist J.J. Berzelius (Jacobsen, 2006: 745; Lundgren, 2000: 94). The latter also included research results in his textbook which a periodical, Poggendorff's *Annalen*, only subsequently asked for permission to reprint (Blondel-Mégrelis, 2000: 238). The committee and these cursory examples suggest that textbooks may be more than simple echoes from the frontiers of scientific research.

Most of us have a basic impression of science textbooks similar to the one represented by news headlines or the university's devaluation of textbook writing. This impression probably stems from our own encounters with textbooks. Sooner or later we all encounter scientific textbooks. Some will be intrigued and fascinated by the insights presented while others experience the insights as incomprehensible or boring. For long I belonged to the latter category. However, as I began my elective subject in physics at the university I read a history of science classic: T.S. Kuhn's (1922-1996) *The Structures of Scientific Revolutions* (1962). Inspired by Kuhn's descriptions of science textbooks and pedagogy, I became interested in textbooks as historical sources and the stories they may tell. Thus, I wrote my bachelor's thesis at the History of Ideas programme on the introduction of new knowledge about atoms and quanta in textbooks for the the Danish "Gymnasium", i.e. the high school system, between 1915-1954. My bachelor's thesis largely relied on Kuhn's descriptions of textbooks but in later projects I have approached textbooks from other positions, e.g. M. Foucault's (1926-1984) *Discipline and Punish: the Birth of the Prison* (1975) or actor-network theory.

In other words, textbooks may be approached from a variety of angles and in the historiography they have been used for an equally wide spectrum studies. The following three brief references display some of the spectrum's ranges:

1. Latour & Woolgar have suggested following the circulation of statements in the construction of scientific facticity between different kinds of texts including textbooks (Latour & Woolgar, 1986: 75-88).
2. Warwick has studied how audiences made sense of and taught physics using J.C. Maxwell's (1831-1879) *A Treatise of Electricity and Magnetism* (1873) (Warwick, 2003).
3. Seligardi has studied how the new anti-phlogistic chemistry was incorporated in and synthesized with the existing frameworks of chemistry in early nineteenth century textbooks from Italy (Seligardi, 2006).

This master's thesis analyzes and discusses the content, form, and function of textbooks in *knowledge infrastructures*. In analyzing textbooks I am interested in discussing the *active* role of textbooks in scientific disciplines as seen from the perspective of knowledge infrastructures. My empirical focus will be chemistry in Copenhagen from c.1820-1850. For instance, I am interested in considering the content of textbooks and their uses for establishing chemistry as an academic discipline. In the remainder of this introduction, I will briefly elaborate on my choice of actors, time span, and geography as well as provide an overview of the thesis.

Demarcation and definition

Chemistry in Denmark has been the subject of various studies including H. Kragh & S.A. Petersen's book on technical or industrial chemistry (Kragh & Petersen, 1995), O. Bostrup's of the chemical revolution in Denmark (Bostrup, 1996), A. S. Jacobsen's Ph.D., and subsequent articles, (mainly) on Ørsted (Jacobsen, 2000a; 2000b; 2006), and A. K. Nielsen's Ph.D., and articles, on chemical periodicals and networks in Denmark (Nielsen, 1998; 2000; 2008).

In the history of science in general, including the history of chemistry, textbooks are far from unprecedented as sources (see section (1) below). However, I draw on a different approach than the existing studies of chemistry and textbooks in Denmark. I suggest viewing knowledge production and identity creation as occurring within *knowledge infrastructures* under the inspiration of P. Edwards (2010) and the conceptual framework of *Large Technological Systems* (LTS). Central questions to my thesis are what roles or functions textbooks may serve as elements in the infrastructures of chemistry, or how textbooks may active attempt at manipulating the infrastructures. I develop these questions in more detail in section (1) which places my thesis as a continuation of recent scholarship on textbooks and outlines my theoretical framework.

My title implies a focus on chemistry in Copenhagen. I am not making a major claim of a type of chemistry uniquely existing in Copenhagen in this particular period. Rather, I am taking the consequence of focusing on textbooks written for the institutions in Copenhagen by chemists residing in Copenhagen. Previous work by Kragh (and in part Jacobsen) on the nineteenth century chemistry in Denmark has de facto focused on Copenhagen institutions and dismissed the possible importance of the university of Kiel in Schleswig-Holstein (under Danish administration from 1773-1864) (See Kragh, 1998a: 235-236; 2016: 25; Jacobsen, 2005: 270-273). I have not studied the relations between Copenhagen and Kiel, e.g. relations of leading figures, exchange of personnel, or knowledge. I have focused on textbooks written by chemists employed at institutions in Copenhagen and thus my title.

In the four volume *Dansk Naturvidenskabs Historie* (History of Science in Denmark) the period from 1800-1850 is designated "Ørsteds halve århundrede"[1] and Kragh has described the scientific environment as "marked" by the presence and "shadow" of Ørsted (Kragh, 2005: 229; 2016: 11). Ørsted was undoubtedly *the* central figure but I focus instead on Zeise, Forchhammer, and Scharling (see section 2.1 for their biographical data, for Ørsted's importance, Kragh, 2005: 239). Though less central than Ørsted, they have long been part of the Danish historiography of science and Kragh describes Zeise as the most important chemist of his time in Denmark (Kragh, 2005: 319) (For Danish historiography of science see (Scharling, 1857: 71-72; Lundbye, 1925: 369-374; Veibel, 1939: 155-192; Jensen, 1983: 465-480; Kragh, 2005: 317-325). However, their textbooks have received less explicit attention in the existing historiography and I am interested in how their textbooks contributed to a knowledge infrastructure of chemistry.

The time span from c.1820 to c.1850 is, as any historical demarcation, pragmatic and contingent. The period is interesting because the university of Copenhagen got its first chair in chemistry in 1822 and the *Polytekniske Læreanstalt* (Polytechnic College) was established in 1829. In other words, this is a period where chemistry is being established as an academic discipline and my thesis considers how textbooks participated in this process. The endpoint around 1850 is defined in part by the death of Zeise, the first professor of chemistry at the university, and partly by the establishment of a separate faculty of science (until 1850 the sciences had resided under the faculty of philosophy) (Kragh, 2016: 25-35).

Overview

My thesis has two main parts each consisting of a number of sections. Each section is provided with a specific number which I will use for referencing internally in my thesis.

The first part outlines the relationship between my thesis and existing scholarship on history of chemistry and scientific textbooks. In section (1.1) and (1.2) I argue for evaluating the bulk of earlier textbook studies as *indicative* studies and describe a historiographical countermovement evaluating textbooks as *active factors* as well.

[1] "Ørsted's half century". Throughout the thesis I quote Danish terms in the main text and provide provisory translations in the footnotes. This is also the case for some chemical nomenclature where translations are provided though possibly anachronistic. Also, I retain some Danish terms in the text rather than using the translation, e.g. writing *Grunddele* rather than fundamental parts in the main text. When doing so the term is in italics.

In section (1.3) I consider some earlier historiographical considerations of the infrastructure vocabulary, and I suggest developing the infrastructural vocabulary to fulfill historiographical aspirations of the textbook studies field. Section (1.3.1) defines my theoretical approach based on Edwards' knowledge infrastructures. The first main part also includes biographical sketches (2.1) and a historical overview (2.2).

The second main part of my thesis consists of 4 sections and my conclusion. I have three sections based on analyses of textbooks by Zeise, Forchhammer, and Scharling. The fourth, and final section of part two, is my discussion of my findings and the theoretical argument.

The second main part is built up as follows: I first focus on classifications of knowledge (section (3)) before analyzing the discussions and role of atomic theory in the chemical textbooks (section (4)). The third empirical analysis focuses on the function of textbooks in practical laboratory training (section (5)). Finally, in section (6), I provide an overview of my empirical findings and discuss the infrastructural terminology in relation to the question of textbook agency. The second main part ends my thesis with the conclusion (section (7)).

1 - Challenging the tradition of indicative textbooks

In the following I discuss different positions in the field of science textbook studies. I suggest analyzing the historiography by discerning between *indicative* and *active* conceptions of textbooks. Furthermore, I argue that historiographical ambitions of the field might be met by analyzing textbooks in terms of *knowledge infrastructures*.

The distinction between *indicative* and *active* is inspired by R. Koselleck's (1923-2006) conceptual history. Concepts, he writes, are at once indicators and factors. They are indicators in so far as the historical context and the experiences of actors represent themselves in their vocabulary. By studying the changing experiences and meanings embedded in concepts like democracy, historians can map out changing, overlapping, and new meanings across time (Koselleck, 2007: 71-72), Put differently, the words can indicate changing attitudes towards democracy. However, concepts may also outline a potential reality and by doing so the concept directs the attention and efforts towards a specific goal. Concepts in this sense are factors of historical change, or they are active, when they direct actors and actions towards specific ends (Koselleck, 2007: 52,72).

Koselleck was open to expanding parts of his conceptual history to more than concepts and wrote that entire sources, like books or monuments, may display conceptual characteristics (Jordheim, 2012: 166). Following a broader notion of 'concepts', textbooks may be analyzed as indicators and factors. In the following I argue that the bulk of earlier research mainly used textbooks as indicative sources. Sections (1.1.1 and 1.1.2) explore this distinction in the historiographical history and from (1.2) I discuss how to strengthen the conceptualization of textbooks as factors.

1.1 - Historiographical traditions

1.1.1 - The indicative tradition

Textbooks are far from unprecedented sources in the history of science. Already in 1948 George Sarton (1884-1956) requested a history of science based on textbooks, but often it is Kuhn who is credited as the point of emergence for interest in textbooks in recent historiography (For Sarton, see Simon, 2013: 653; For Kuhn, see for instance Badino & Navarro, 2013b: 8). However, Kuhn's notion of textbooks almost renders them useless as historiographical tools (Badino & Navarro, 2013b: 9). Textbooks, Kuhn thought, necessarily rewrite their contents to display a narrative of continuity and thereby obscures the actual history (Kuhn, 2012: 135-136). According to Kuhn textbooks aim at quickly acquainting students with the experiments, concepts, laws, and theories and to do so in the contemporary vocabulary of a scientific community. Thus, textbooks "address themselves to an already articulated body of problems, data, and theory" (Kuhn, 2012: 136,139). Due to their introductive purpose textbooks were only the prerequisite for the "creative scientist", i.e. creative science picks up where textbook science stops (Kuhn, 2012: 20). The historian studying textbooks would thus encounter "the body of accepted theory" but not the creative science of researchers (Kuhn, 2012: 10).

Kuhn's notion of textbooks was reiterated by David Knight (1936-2018) in his *Sources for the History of Science, 1660-1914* (1975). Here textbooks convey "normal science" from one generation to the next. By consequence textbooks are "dull compilations" only differing in their "up-to-dateness". The historiographical use of textbooks is their display of accepted knowledge and indications of the progress or retardation of knowledge by studying successive editions of the same textbook (Knight, 1975: 130, 140-141).

In 1987 H. Kragh published his *Introduction to the historiography of science* which supported this conception of textbooks. In textbooks, Kragh wrote, historians would not find any "creative research" but rather a conservative indication of what was conceived as unproblematic and stable knowledge (Kragh, 1987: 125-126).

In a Danish context empirical studies informed by an indicative approach would be Riis-Larsen (1991), Bostrup (1996), and Tapdrup (1998). The latter, for instance, studied a variety of textbooks to assess what natural philosophers understood by the term natural philosophy in the eighteenth century (Tapdrup, 1998: 4-7). More recently Historian of physics J. Simon has argued that internationally historians of physics are still mainly interested in textbooks as sources for the standard knowledge in a given period or for studying paradigm changes (Simon, 2013: 669). In other words, they use textbooks similarly to the ways described by Kuhn, Knight, and Kragh.

1.1.2 - STEPs challenge

Until recently textbooks arguably has a negative historiographical connotation due to a bias towards novelty in the history of science (Secord, 2004: 662; Vicedo, 2012: 83). During the 2000s, however, a historiographical countermovement took up textbooks. One participant in these efforts described the standard image of textbooks as opposed to novelty. Rather, textbooks were seen as the "last existential act of scientific creation", i.e. as far from creative science as possible (Brooke, 2000: 1). The countermovement, as I see it, was centered around the *Science and Technology in the European Periphery*-programme (STEP), publications like *Communicating Chemistry: Textbooks and Their Audiences, 1789-1939* edited by Lundgren & Bensaude-Vincent (2000), and the special issue of *Science and Education* edited by García-Belmar et al. (2006).

STEP formulated a positive *re*evaluation of textbooks (Badino & Navarro, 2013b: 8). Historian of chemistry B. Bensaude-Vincent stated that STEP wanted to put "textbooks on the map of science studies" (Bensaude-Vincent, 2006: 667). They were actively challenging traditional diffusionist frameworks in the history of science, like the distinction between centre and periphery, where scientific knowledge was fashioned in centres and then transmitted like a "commodity" to the passive receivers in the peripheries (Gavroglu et al., 2008: 159). Challenging these situations of knowledge exchange, STEP naturally also took up the communication of science (e.g. teaching situations). The teaching of science had been seen as structurally similar to the relationship between centers and peripheries: teaching was unidirectional and students the passive receivers of knowledge. Likewise, the peripheral teacher was merely echoing the creative science of the centre. By contrast STEP wanted to see teachers and students as active in the creation of scientific knowledge (Gavroglu et al., 2008: 163). This resulted in an interest in studying how recipients actively made sense of lectures, theories, and textbooks. One recent empirical example challenging the notion of passive reception is García-Belmar & Bertomeu-Sánchez (2015). They have studied notebooks written by attendants at the chemist L.J. Thenard's (1777-1857) lectures at the French *Collège de France* in the early nineteenth century (García-Belmar & Bertomeu-Sánchez, 2015: 601). They argue that notebooks result from students' "creative appropriations" and thus cannot be read as indicating what was actually said by a lecturer (García-Belmar & Bertomeu-Sánchez, 2015: 600-601).

The indicator-factor perspective on teaching and textbooks is present in different STEP-contributions. Bensaude-Vincent may be taken as an example. She has described teaching as central to science as it contributes to the "disciplinary partitions of scientific knowledge", i.e. it actively shapes notions of scientific knowledge. Textbooks are read indicatively as important "archeological traces" of former disciplinary partitions (Bensaude-Vincent, 2006: 668). In other words, teaching is active process and here textbooks are indications.

A more empirical example of studying textbooks as factors could be Jacobsen's study of Ørsted's didactics and textbooks (Jacobsen, 2006). According to Jacobsen the aim of Ørsted's teaching was the establishment of a dynamical world view as the basis for research and teaching. For this he needed his own textbooks to announce and propagate his theories (Jacobsen, 2006: 745). Ørsted's textbooks are thus not mere indications of stable knowledge.

Within the last decade other scholars have requested textbook studies focusing more on textbooks as factors, or active. In the next section I review these calls for active textbooks before I propose approaching it from an infrastructural approach.

1.2 - Calls for textbook agency

In 2013 M. Badino and J. Navarro co-edited *Research and Pedagogy*: *The history of Quantum Physics through Its Textbooks* (2013a). In their introduction they request an evaluation of textbooks as more than the outcome of scientific change (as implied in Kuhn's body of accepted theory). They also want to analyze textbooks as "*active agents*" in scientific change (Badino & Navarro, 2013b: 14, italics in original). Their argument seems obvious: science does not change overnight and textbooks are published before, during, and after scientific change (Badino & Navarro, 2013b: 14). Tracking change in textbooks across some shift in the knowledge of a scientific discipline could, however, just reiterate an indicative textbook approach. Additional insight is gained from the anthology's epilogue written by historian of physics D. Kaiser. Kaiser criticizes the tradition using textbooks to "reconstruct" the path of scientific change. This tradition, Kaiser writes, believes textbooks "reflect" an almost teleologically given path in scientific development without "affecting" the path (Kaiser, 2013: 286). Using Koselleck's distinction between indicators and factors previous textbooks studies have read textbooks solely as indicators of scientific knowledge and forgotten their active aspect as factors.

Kaiser states that textbooks are not passive reflections but actively contribute to the development of scientific knowledge. In the case of the development of quantum theory, Kaiser argues, many possible approaches presented themselves to scientists but gradually a narrowing of approaches emerged. The question is how? Kaiser argues for studying how textbooks contribute to "reduce the ever-multiplying possibilities" and the production of an apparently "recognizable conceptual path" (Kaiser, 2013: 283-284). *Research and Pedagogy* is focused on textbooks as "agents of research", but I wish to take up their lead and discuss ways of seeing textbooks as active in addition to their indicative characteristics (Badino & Navarro, 2013b: 16).

Cultural historian A. Grafton has proposed an analytical distinction for scientific textbooks which implies their functions as factors. Grafton states that textbooks both *form* and *inform* their readers. In Grafton's introduction to the co-edited book *Scholarly Knowledge: Textbooks in early modern Europe* (2008) he describes modern scientific textbooks as more than formulae (Grafton 2008: 23). Textbooks also prescribe models of comportment and practice. Reading textbooks students are not just to be *informed* of the status quo of a discipline but simultaneously to be *formed* as scientists. Grafton exemplifies with a historical author who wished to enhance the skills of his readers as well as transforming their values (Grafton, 2008: 23). I elaborate on how the distinction between inform and form is used in my thesis in section (1.3.3b) below.

Grafton stresses a difficulty of placing textbooks into their "*Sitz im Leben*", i.e. "reconstructing" the intentions and practices of their authors or users. The problem is placing texts in the conflicts among authors, readers, books, and actual learning (Grafton, 2008: 26, original emphasis). This problem, and the matter of active textbooks, is not solved once and for all but benefits from being approached from the perspective of infrastructures and networks as I will argue in the following section.

1.3 - Actualizing a Potential Tradition for Textbook Agency

In this section I wish to address some potential formulations of a network informed approach to textbooks predominately made by later STEP-contributors or uttered as part of the STEP-programme. In other words, the vocabulary of knowledge infrastructures to which I turn in the subsequent section (1.3.1) is not completely alien to the STEP-community who are central in the recent positive historiographical reevaluation of textbooks. However, the positions I outline before turning to Edwards' knowledge infrastructures have mainly been focusing on *social networks*, i.e. on humans and their interactions. By including Edwards I suggest expanding the list of network participants beyond humans in order to see textbooks as active.

In 1995 F. Abbri and later STEP-contributor Bensaude-Vincent co-edited *Lavoisier in European context: negotiating a new language for chemistry* based on attempts at remapping the chemical revolution through a "decentralized approach of localities" (Bensaude-Vincent, 1995: 6). The book shares aspirations with the later STEP-programme as seen in the contribution by historian of chemistry Anders Lundgren. Lundgren reflects on how novel questions may be posed if the chemical revolution was watched from the "fringes" rather than the centre (Lundgren, 1995: 19). This of course easily translates into STEP's focus on peripheries.

Of more significance to the potential formulations of network approaches is Bensaude-Vincent's network-inspired model of knowledge circulation put forth in her introductory essay. She suggests challenging a simple diffusion model of scientific knowledge from a "stable nucleus" by conceptualizing "diffusion" as occurring within a "polymorphous and multipolar network" (Bensaude-Vincent, 1995: 9, 13). From this vantage point, the success of theories or practices could be seen as the successful "reshaping of a pre-existing network". Actors, e.g. chemists, working in these networks could be seen as local network controllers capable of altering portions of the network according to their social prestige and institutional affiliation (Bensaude-Vincent, 1995: 12). An empirical example of this local network control could be Thenard's central position in the French educational system. Due to his "prestige and authority" Thenard's textbook became a reference in the French system, and the Ministry of Public Instruction officially presented it as a model for all teachers. Consequently, most French textbooks adopted Thenard's mode of classifying chemical elements though many other possible classifications existed (Bertomeu-Sánchez et al., 2002: 236-237).

Bensaude-Vincent's multipolar networks are social networks. A similar focus may be seen in the book *Travels of Learning*: *A Geography of Science in Europe* (2003) co-edited by Simões, Carneiro, and Diogo on the basis of a project started by STEP (Simões et al., 2003a: xiii). In one line at the end of their introduction Simões et al. suggest developing "the notion of a network of practitioners" for use in historical analysis, i.e. a social network of humans (Simões et al., 2003b: 14). The contribution by García-Belmar & Bertomeu-Sánchez may serve as a brief example of this social network focus. García-Belmar & Bertomeu-Sánchez are describing *"pensionados"*, i.e. young students travelling abroad to centres like France from Spain (García-Belmar & Bertomeu-Sánchez, 2003: 144). In France a (social) network of veteran *pensionados* facilitated the new student's admission to teaching, accommodation, and general guidance (García-Belmar & Bertomeu-Sánchez, 2003: 164).

In a Danish context, and independently of STEP, chemistry has been linked with a network terminology by A.K. Nielsen. However, with her focus on the use of periodicals and societies in creating identities she has, understandably, focused on human interactions or social networks (e.g., Nielsen, 1998: 180; Nielsen, 2007: 199-202). Before my elaboration of Edwards' knowledge infrastructures I return to another STEP-contribution which actually noted the possibility of non-human elements in networks.

The contribution is Gavroglu et al.'s (2008) historiographical considerations. In their attempt at describing knowledge circulation Gavroglu et al. discuss the importance of scientific "sites" and the travels between them. Sites and people are described as "specific nodes" in networks. Depending on the case the networks may be fluid or hierarchical, and more or less extended structures representing the "mediation of ideas, practices and instruments" in different nodes (Gavroglu et al., 2008: 161-162). The important novelty in Gavrolgu et al.'s conceptualization of networks is that individuals, instruments, or structures like institutions may function as nodes (Gavroglu et al., 2008: 162). In this broadening of the possible cast of nodes suggested by Gavroglu et al. I will include textbooks. I will elaborate on this inclusion in the following section. In the following section I elaborate on Edwards' knowledge infrastructures and on ways of thinking about textbooks as infrastructural elements.

1.3.1 - Knowledge infrastructures

The network approach sketched by Bensaude-Vincent (1995) or Gavroglu et al. (2008) has not been sufficiently elaborated and I suggest doing so by drawing on Edwards (2010). Edwards has elaborated on how to apply LTS-informed theory to the matter of knowledge construction. It is his thoughts on *knowledge infrastructures* which provide the basis for my continuation of the network approaches described above.

Edwards' knowledge infrastructures are comprised by "*robust networks of people, artifacts, and institutions*" which are orchestrated as to contribute to the generation, sharing, and maintenance of knowledge (Edwards, 2010: 17, italics in original). Edwards defines the systems and infrastructures as socio-technical because they require the cooperation of people, technology, and natural objects to construct the knowledge of any given discipline (Edwards, 2010: 8, 17). For instance, a scientific community must share standards and norms to ensure the compatibility of their actors, theories, and models. On a material side the community needs research objects and facilities like classrooms or laboratories (Edwards, 2010: 17).

Edwards is not explicit on what actually constitutes a scientific community's or discipline's network. Of course, no ahistorical blueprint for such a network exists but as a practical, heuristic definition I use is M.J. Nye's "disciplinary identity" (Nye, 1993: 274). At one point she describes a disciplinary identity as "a network of elements", e.g. common idols, classic literature, common practices, formal insitutions, and shared values (Nye,1993: 19-31, 274). The classic literature explicates common vocabularies and theories sometimes attributed to historical heroes, e.g. Newton, though their works may not be read. For laboratory sciences common practices and norms will often be learned in the laboratory, e.g. by introduction to instruments and experimental practices (Nye, 1993: 24-25). Thus, this more physical aspect is also included in the network of disciplinary identities.

1.3.2 - Systems, networks, infrastructures

Before explaining the place of textbook in infrastructures, a precision of terminology is of use. In his exposition of LTS Edwards describes how system builders orchestrate "linked sets" of entities in order to fulfill a functional need. Setting up systems, however, is more than inventing or collecting objects and instruments. It requires the linking of skills, knowledge, people as well (Edwards, 2010: 10). Education may serve as an example: the educational system requires the organization of teachers, students, institutions, and objects needed for their studies (like educational and instructional texts) to satisfy its function of training students. Again, systems are socio-technical.

If system builders wish to connect their local system with outside systems to strengthen them or to integrate other systems (to resolve tensions between competing systems) *gateway technologies* are introduced. These gateways allow for the connection of previously incompatible systems and vice versa: the non-existence of gateways demarcate systems (Edwards, 2010: 10-11). Edwards does not explicitly define gateways. He provides a few examples of which electrical converters between alternating and direct current circuits are the most self-evident. However, gateways need not be technological. Trading unions are political gateways allowing the passage of goods between otherwise closed national systems (Edwards, 2010: 10-11). Below I describe how textbooks can be considered a concrete example of gateways.

Establishing gateways between heterogeneous systems results in a change of level. Linked heterogeneous systems are "*networks* or, at a higher level, *webs*". The former "links stand-alone systems" and the latter different networks. In general, Edwards adds, infrastructures are networks or webs rather than systems (Edwards, 2010: 11-12). Thus infrastructures can be taken as synonymous with networks and in the remainder of the thesis I describe disciplines like chemistry as knowledge infrastructures.

A knowledge infrastructure of chemistry with its theories, norms, and facilities may be described more accurately by distinguishing analytically an *immaterial* and a *material* portion of the infrastructure. The *immaterial* are the norms, theories, or rules while the material aspect could be laboratories, instruments, and things.

Proceeding from this general overview of the infrastructural terminology I begin my interpretation of Edwards' theory in conjunction with textbooks. Edwards' infrastructural theory of knowledge has interesting perspectives in which I want to place the textbook as an important element.

1.3.3 - Textbooks and infrastructures[2]

Infrastructures require a range of participants and a standardization of practices or actions to fulfill its functional need. In other words, infrastructures favor or enforce certain actions whereby participants are suggested or required to act in specific ways. In this sense infrastructures and their elements actively change or affect actions. Edwards has provided the example of the car-road-infrastructure. This infrastructure allows for great mobility but partly defines *where* it is *possible* to go (Edwards, 2003: 191). Our cars are not geared for driving off-road and thus drivers are more inclined to follow the roads. The freedom of the open highway is, in this sense, limited.

Continuing this line of thought- applying the infrastructures to knowledge, and by including textbooks as elements - Edwards' theory opens for seeing textbooks as active, rather than mere passive vehicles of knowledge. Textbooks as infrastructural elements may contribute actively to the correction, inspiration, or enforcement of possible actions by infrastructures (Edwards, 2010: 12). In order for an infrastructure to work it requires that participants act and think in a specific way, they must be *standardized*. The standardized ways of thinking or acting may be verbally prescribed or the infrastructure may simply render certain actions

[2] I should note here that I have previously handed in a portfolio exam on the subject of textbooks and networks at the History of Ideas Programme, Aarhus University (December, 2017). However, in the portfolio I argued for textbook agency from the perspective of actor-network theory.

impossible (Edwards, 2010: 12). My thesis defines textbooks as active when they play a central role in an infrastructure or tries to alter the constitution of the infrastructure (alternatively, in networks).

The question of altering infrastructures brings forth a defining characteristic of infrastructures. Edwards employs the concept of *inertia* to describe the tension between existing infrastructures and attempts at remodeling or restructuring them (Edwards, 2010: 9). Infrastructures are complex and are therefore never changed "from above" (Edwards, 2010: 9). Changing complex infrastructures takes time and local adjustments which cannot be controlled from one central point in the infrastructure.

In the following I present two ways textbooks may be active infrastructural elements. These ways form the basis for my empirical analysis of Danish chemical textbooks. Firstly, textbooks can be used to demarcate a discipline by erecting or dismantling gateways to other knowledge infrastructures like physics. Secondly, while serving as entry points into the chemical infrastructure textbooks present students with the results and norms of chemistry, i.e. textbooks actively inform and form aspiring chemists.

1.3.3a - Gateways

Textbooks can act as, or manipulate, gateways to other knowledge infrastructures. Consequently textbooks can contribute to the integration or separation of knowledge infrastructures. The early days of quantum chemistry may serve as an empirical example of textbooks *as* gateways. Here a gateway had to be made between quantum theories and chemistry as a discipline. Gavroglu & Simões have argued certain textbooks established these and tried to consolidate a consensus on terminology and practice between these two infrastructures of knowledge (Gavroglu & Simões, 2000: 415-416). Similarly, explicitly discussing the gateways between chemistry and other knowledge infrastructures is a way of discursively demarcating oneself and legitimizing certain theories or practices.

In both instances of gateway-textbooks I would describe the textbooks as manipulating gateways in chemistry's immaterial infrastructures. The former by establishing gateways between disciplines and theories. The latter by discussing what may be classified as chemical knowledge, i.e. by dismantling or erecting gateways between different theories, observations, or knowledge infrastructures.

1.3.3b - Form and inform

In time infrastructures become naturalized, invisible, in their everyday familiarity of its users. In successful infrastructures objects, e.g. instruments, "blend seamlessly with thinking, talking, and writing" (Edwards, 2010: 9,18).

This familiarity, the seamless cooperation, requires initiation and will appear unnatural to the uninitiated. Infrastructures are learned via membership and the initiation may be by apprenticeship or formal education. Regardless of the structure of the initiation textbooks may contribute as they instruct and stipulate required forms of action for students. Textbooks, then, constitute *entry points* through which students are introduced to a specific organization of the elements constituting the infrastructure of chemistry.

Kaiser has dubbed this initiation purpose of textbooks "generational reproduction" (Kaiser, 2005b, 6). Textbooks reproduce communities by passing down skills and knowledge to a new generation of practitioners. Textbooks also aim at inculcating norms of scientific practice and a specific organization of the disciplinary landscape (Kaiser, 2005b: 6; Bensaude-Vincent, 2006: 668). By developing norms and organizing the disciplinary landscape textbooks are intended to actively form students and introduce them to the knowledge infrastructure. For instance, by answering the question, *how is our own infrastructure organized and how does it relate to other disciplines?* This exemplifies the formative aspect of Grafton's distinction between textbooks as formative and informative.

Grafton's general distinction is strengthened analytically by including insights on norms and textbooks from an article by Bensaude-Vincent (2007). Textbooks, she writes, communicate norms on three levels: *practical rules*, r*equirements*, and *obligations*. *Practical rules* are simple rules of thumb with no ethical meaning, i.e. they focus on practicality rather than goodness. *Requirements* are widely accepted rules or ideals, e.g. empiricist notions that facts have absolute priority or 'the scientific method' in general. Finally, obligations are prescriptions of what 'chemists do' and how to deal properly with nature (Bensaude-Vincent, 2007: 141). Bensaude-Vincent's levels of norm communication suggests ways of studying textbooks and how textbooks tries to standardize the actions or norms of readers.

In terms of my distinction between immaterial and material infrastructures textbooks may interact with the infrastructure in different ways. For example, a textbook trying to alter or establish norms in the infrastructure is interacting with the *immaterial* portion of the knowledge infrastructure. By contrast, a textbook providing practical instructions, rules of thumb, is interacting with the material portion of the knowledge infrastructure.

1.4 - Conclusion

On the basis of these historiographical considerations I suggest analyzing textbooks as infrastructural elements to emphasize the *factor*-aspect of the indicator-factor duality. It is a duality and thus textbooks are indicators as well. However, as I have argued textbook studies have been inclined towards the *indicative* tradition of Kuhn, Knight, and Kragh. A critique noted by Simon (2013) and Kaiser (2013) as well.

To provide concrete, analytical tools I suggest analyzing textbooks in relation to infrastructural elements. Textbooks can either act as an important element, or they can manipulate existing infrastructures. In the former case they contribute to the standardization of norms and actions demanded by the infrastructure. In the latter, textbooks have to wrestle with the inertia of infrastructures.

The section (3), (4), and (5) aim at empirically substantiating my theoretical argument. The first two primarily focus on the immaterial portion of infrastructures. Section (5) suggests functions of textbooks in a more material portion of the knowledge infrastructure: the training laboratory. Before engaging in these empirical sections I provide, in section (2), a biographical sketch of Zeise, Forchhammer, and Scharling, and I give a general outline of chemistry from c.1800-1840.

2 - Biographies and historical developments

The first subsection here, (2.1), provides biographies of authors whose textbooks I analyze in depth in the subsequent sections. The biographies also describe what books I have analyzed. In the part (2.1.4) I reflect on my definition of textbooks. The second subsection (2.2) is a more general outline of the historical developments in chemistry.

2.1 - Biographies

2.1.1 - W. C. Zeise (1789-1847)

Zeise was an apothecary's son, and from 1806 he was housed by and under the guidance of Ørsted. He assisted Ørsted and attended lectures in chemistry while preparing for university enrolment. In 1815 he passed the pharmaceutical examination and by 1818 he became a doctor of philosophy (Ørsted, 1920: 555-558)

In nineteenth century Europe it was customary for intellectuals or "men of science" to travel from peripheries to centres of science (Simões et al., 2003: 2-4). Zeise was no exception to this custom and in 1818-1819 went on a *Wanderjahre* (Ørsted, 1920: 558). He visited the chemist Chr.H. Pfaff (1773-1852) in Kiel before visiting the chemist F. Stromeyer's (1776-1835) Göttingen as he had been recommended (Kragh et al., 2008: 195). Zeise described his travels in a report written for the fund covering most of his travel expenses. There he described how he keenly observed the practical instruction of students in order to be acquainted with the details of Stromeyer's teaching method. He attended Stromeyer's lectures on analytical chemistry and trained analytical chemistry. In his recollection for the fund Zeise describes how this kind of chemistry did not demand the most inventive chemist but numerous "Smaaerfaringer"[3] which can hardly be taught in any other way than learning by doing. A competent teacher would only be able to convey his insights on a continuous basis as the student encountered novel phenomena (Sylvest, 1972: 66, I-II[4]).

[3] "minor experiences" (literally translated)

[4] C. Sylvest's thesis features transcriptions of archival material as appendices. The first page of each appendix continues the pagination of his thesis. If, however, the appendix spans multiple pages he uses a sub-system of roman numerals for these. Thus, (Sylvest, 1972: 66,I-II) reads as page 66, marking the beginning of an appendix, and the pages in this appendix I-II.

Zeise was influenced by Ørsted's anti-atomism but in Paris Zeise's ideas were challenged. In his travel report Zeise described how atomism was an absurdity in German natural philosophy. However, in Paris atomism was the only certain hypothesis. Gradually Zeise acknowledged atomism's merits: it supplied facts, and with clarity ordered and presented the explanations of these facts (Sylvest, 1972: 66,V-VI)

Upon returning home Zeise needed financial support from his travel fund again. Papers reveal that by 1819 he was intent on writing a textbook in chemistry which, according to Sylvest, was his 1829 textbook: *Udførlig Fremstilling af Chemiens Hovedlærdomme saavel i theoretisk som i pracktisk Henseende* [A comprehensive exposition of the main doctrines of chemistry with regards to both the theoretical and practical part] (Sylvest, 1972: 16).

Zeise's main teaching activities were between 1820 and his death in 1847 with periodic leave due to illness (Sylvest, 1972: 23-24). In 1822 he was appointed as professor in chemistry at Copenhagen university and was in charge of the practical chemical instruction. Zeise also taught chemistry at the Polytechnic Collece when is was established in 1829. As a result Zeise lectured on many different subjects, e.g. inorganic, organic, and technical chemistry (Sylvest, 1972: 21-22). Ørsted's memorial volume on Zeise includes remarks on his teaching. Zeise's lectures were uninspiring but marked by thoroughness and order. Thoroughness and order were ideals Zeise sought to convey to aspiring chemists. Accordingly Zeise is noted for having required strict "Nøiagtighed, Orden og Flid"[5] (Ørsted, 1920: 561, 564)

My study of Zeise draws on a variety of sources. I have studied his 1829 textbook and his handbook on organic chemistry, *Haandbog i Organiske Stoffers almindelige Chemie* [Handbook on the General Chemistry of Organic Substances] (1847). I will refer to the latter as Zeise's *Haandbog* in the remainder of the thesis. In addition to these works, Zeise was working on a textbook in the 1840s entitled *Anvisning i praktisk Chemie eller Konsten at indsamle og anvende chemiske Erfaringer* [Instructions in Practical Chemistry, or the Art of Collecting and Applying chemical Experiences]. Only the introduction was printed in article form (from here on referred to as the *Anvisning*) (Zeise, 1844). I have also studied an undated manuscript discovered in 1997 and published by chemist-historian H.T. Nielsen as *Maximilian Bruhns Zeise-bog* (1999). The manuscript is titled *Nærmere Anviisning i analytiske Undersøgelser over et Udvalg af organiske Stoffer* [A more specific Instruction in

[5] "accuracy, order, and diligence"

analytical investigations on a selection of organic substances]. Nielsen dates it to around 1835 and it provides information on what a practical course in chemistry encompassed under Zeise (Nielsen, 1999: 10, 15). I have supplemented these publications with some of Zeise's lecture notes kept at the Royal Danish Library.

2.1.2 - J. G. Forchhammer (1794-1865)

Forchhammer was born in Husum, present day Schleswig-Holstein, and became an apothecary's apprentice. In 1815 he enrolled the University of Kiel to study chemistry and pharmacy under Pfaff, and eventually he became Pfaff's laboratory assistant (Johnstrup, 1869: xi-xiii). In 1818 Forchhammer arrived in Copenhagen and was introduced to Ørsted. Only speaking German he spent some years learning Danish while working with Ørsted in the laboratory. Forchhammer acquired the title doctor of philosophy on his dissertation *De Mangano* (elaborating on studies by Pfaff) in 1820 (Johnstrup, 1869: xv; Nielsen, 1994: 20).

During his *Wanderjahre* from 1820 Forchhammer went to England and encountered some of the great English chemists, e.g. J. Dalton (1766-1844) and W. Prout (1785-1850) (Johnstrup, 1869: xix-xxii). Forchhammer returned to Denmark and was hired as a laboratory technician for the Royal Porcelain Factory in 1822. The salary was insufficient and thus Forchhammer was ready to leave Denmark. However, Ørsted arranged for him to become an associate professor in chemistry and mineralogy at the university in 1823 (Johnstrup, 1869: xxiii; Nielsen, 1994: 21). Forchhammer also taught at the Polytechnic College when it was established and from 1831 he was made professor of mineralogy at the university (Nielsen, 1994: 21). In the early 1830s he also lectured chemistry at Royal Military Academy and Sorø Academy (Johnstrup, 1869: xxxv).

Though it is possibly a bit celebratory a memorial volume on Forchhammer describes his teaching in a manner quite different from Zeise's. Forchhammer was gifted with an ability of engaging the interest of the audience. His lectures were systematic and marked by his enthusiasm for science. Forchhammer was one of the most popular lecturers and his lectures were "klare og indholdsrige"[6] (Johnstrup, 1869: xxxv).

My study of Forchhammer is based on multiple textbooks. During 1830-1831 he published a three volume *Ledetraad ved Forelæsningerne over Chemi ved den Kgl. Militaire Høiskole*

[6] "clear and informative"

[Guide for the chemical lectures at the Royal Military Academy] (from here on simply the *Ledetraad*). In 1834-35 he published an incomplete textbook entitled *Lærebog i Stoffernes Almindelige Chemi*e [Textbook on the General Chemistry of Substances] which seems to be the foundation for his 1842 textbook with the same title. The 1842 textbook is complete but the preface announces the publication of additional volumes which never appeared (Forchhammer, 1842: iii).

2.1.3 - E. A. Scharling (1807-1866)

The last textbook receiving in depth attention in my thesis was translated by Scharling. Like Zeise and Forchhammer, he was an apothecary's apprentice and eventually passed the pharmaceutical examinations. Following his examination he continued his chemical studies and worked in Zeise's laboratory. In 1829 Scharling was hired as Ørsted's assistant in physics at the Polytechnic College with recommendations from Zeise (Veibel, 1939: 188).

In 1834 Scharling graduated the polytechnic examination in applied science - which in practice meant chemistry (Kragh, 2016: 17) - and undertook his *Wanderjahre*. Scharling studied analytical chemistry in J. Liebig's (1803-1873) Giessen but returned to Denmark in 1836 as he was asked to substitute as associate professor in chemistry at *Kirurgisk Akademi* (the Academy of Surgery). When in Denmark he was asked to substitute for Zeise as well (Veibel, 1939: 188-189).

At the end of the 1830s Scharling obtained various teaching positions: he lectured physics and chemistry at the Veterinary School from 1837-1845 and as the Academy of Surgery was closed its teaching was transferred to the university with Scharling as its teacher. After 1839 he was permanently hired as associate professor in chemistry at the technical college eventually taking over from Zeise (Veibel, 1939: 188-189; Kragh, 2005: 318).

My study of Scharling is more limited than those of Zeise and Forchhammer as I have mainly read his translations of German textbooks. The books were F. Wöhler's (1800-1882) *Grundriss der Chemie* translated as *Wöhlers Grundrids af Chemien* in two books, one inorganic (Scharling, 1837) and one organic (Scharling, 1841).

2.1.4 - Defining textbooks

Textbooks are difficult to define historically and have a variety of names in different languages. The English term *textbook* can hardly cover all the meanings of educational material, e.g. "Lehrbuch" (German)¸ "manual" (Spanish, Catalan, Portuguese). Furthermore, instructional books may be designated "Introduction", "Guide", or "Grundriss" like Wöhler's (Bertomeu-Sánchez et al., 2006: 657-658). For the period studied here, one working definition is to approach textbooks as defined by *use* or *purpose* (García-Belmar et al., 2005: 223). The former denotes any text used as a didactic tool while the latter means texts explicitly "designed to be used as a didactic instrument" (García-Belmar et al., 2005: 223). One example of the former could be N. Copernicus' (1473-1543) *De revolutionibus orbium coelestium* which was used as a textbook in Paris and Wittenberg (Grafton, 2008: 26). I have chosen the latter definition. Chemistry textbooks defined by *purpose* are texts that by indication in titles or prefaces were written specifically for the teaching of chemistry, e.g. by being named "lærebog". The textbooks chosen are written by some of the first teachers of chemistry as an academic discipline at institutions in Copenhagen. The only textbooks not written solely by one of the actors were Scharling's translations. However, I will briefly argue these textbooks can be considered as expressing Scharling's views.

First of all, Scharling's preface to the translation states his adherence to the purpose intended by Wöhler (Scharling, 1837: vii). Secondly, Scharling retains Wöhler's original preface in the inorganic textbook. This is important as this is where authors describe the purpose of their work. Historian of science G. Petrou has shown that prefaces and contents were not always retained. Translations were not necessarily "faithful" and translators would omit or add sections to adapt the text to its intended audience (Petrou, 2006: 830-832). In other words Scharling could have omitted the introduction all together had he disagreed. Scharling states that his translation is not literal. He allowed himself "smaa Afvigelser [og] smaa Tilsætninger"[7]. For instance, he substitutes atomic numbers, atomic weights, atoms etc. with "Værdital"[8] (Scharling, 1837: vii).

Before proceeding to the general outline of chemistry there are some methodological problems which needs addressing. First of all, it is difficult to know which textbooks were used as university catalogues only state the subjects of lectures but not the books used (Lundgren, 2000: 92). Here I assume that the teachers employed their own textbooks, though not claiming that they exclusively used their own material.

[7] "minor deviations [and] minor additions"
[8] "numbers of value"

Edwards' infrastructure vocabulary also naturally includes a distinction between *system builders* and *users* (Edwards, 2010: 11). The authors of textbooks, chemists or teachers in institutions, may be regarded as system builders trying to organize systems fulfilling different needs. However, on the recipient side we have system *users* who do not passively adjust themselves to the systems encountered. For instance, Scharling was not a passive receiver of Wöhler's *Grundriss* but adapted the terminology. My thesis focuses exclusively on *system builders* and their textbooks as I have not accessed source material meriting claims on the behalf of users.

2.2 - Chemistry c.1800-1840

The nineteenth century was a century of chemistry (Nielsen, 2006: 119). Elongating the century it could begin with the new chemistry of the 1790s (Kragh, 2005: 316) and end in World War I, sometimes dubbed the chemists' war (Misa, 2004: 195). In the following I outline some of the general developments in chemistry during the first half of the nineteenth century. These developments fill large sections in monographs, e.g. Bensaude-Vincent & Stengers (1996: 92-159), Nye (1993: 1-105) and Klein (2003), so the following will of course not be exhaustive. Still, I include it to provide an overview of the intellectual horizon in which the instances I analyze in greater detail were formulated. This period saw a new emergence of atomic hypotheses (Bensaude-Vincent & Stengers, 1996: 113), novel symbolism, new knowledge in organic chemistry (Klein, 1999: 146), and a general professionalization and institutionalization (Kragh, 1998b: 340). Below I describe changes in chemical theories; atoms and the organic chemistry in subsections (2.2.2) and (2.2.3). In subsection (2.2.4) I turn to institutional developments.

2.2.1 - Organic chemistry and atomic theory

The history of early nineteenth century chemistry may be structured in many ways. Both Bensaude-Vincent & Stengers' history of chemistry and historian of chemistry U. Klein observe a shift in chemical knowledge around 1840. For the purpose of my thesis I focus on the period between 1800-1840, which Bensaude-Vincent & Stengers call "analysis" (Bensaude-Vincent & Stengers, 1996: 103-104; Klein, 2003: 65).

After the chemical revolution chemistry began focusing on simple substances, elements, investigated by analysis and with the precision balance as the instrument of choice. The early nineteenth century was also heavily influenced by Berzelius. Based on experiments with newly invented voltaic pile, i.e. the battery, Berzelius formulated an electrochemical dualist theory of combination around 1810. For instance, salts were unions of two bodies of opposite electrical charge in Berzelius' theory and this was the international definition until around 1840 (Bensaude-Vincent & Stengers, 1996: 104, 109-110).

The dualist theory and precision balance in combination may be exemplified by the "traditional method" of analysis as dubbed by Klein (1999: 152). It assumed the existence of pure chemical substances behaving as relatively stable entities in chemical reactions, i.e. it modeled substances as building blocks (Klein, 1999: 151). For instance, a compound *ab* reacting with *cd* could recombine as: $ab + cd \rightarrow ac + bd$. Chemists studying reactions had to isolate and analyze all the reaction's products. The analysis, and ultimately the understanding of the reaction, was complete if the analyzed reaction products could be resynthesized on the basis of the products found when analyzing the substances. The "paradigmatic" case was salts. Their analysis normally resulted in few, often two, reaction products which were easily isolated (Klein, 1999: 153-154).

However, this method was challenged in the emerging organic chemistry (Klein, 1999: 154). Challenges arose when analyzing in order to calculate chemical formulae, a novelty stemming from atomic theory and Berzelius.

2.2.2 - Atoms and formulae

During the two first decades of the nineteenth century "leading European chemists were fascinated with the idea of mathematizing chemistry" and one could fit J. Dalton (1766-1844) and Berzelius into this description (Klein, 2003: 15). In Denmark Ørsted also described Berzelius and Dalton as attempts at mathematizing chemistry (Ørsted, 1820: 37-38).

Dalton formulated a conception of chemical elements in atomistic terms in 1804. It elaborated on the law of definite proportions (Bensaude-Vincent & Stengers, 1996: 112-113). Dalton added a law of multiple proportions which, in combination with J.L. Guy-Lussac's (1778-1850) law of combining volumes of gasses, was the empirical precondition for Berzelius' new formalism proposed in 1813 (Bensaude-Vincent & Stengers, 1996: 113; Klein, 2003: 12).

Berzelius' formalism is basically the one used today. Combining letters and numbers it eventually represented water as H_2O (From 1814 as 2H+O and by the late 1820s H^2O) (Klein, 1999; 149 incl. note 6). Berzelius' formalism represented his theory of proportions which differed from Dalton's atomic theory. Dalton attributed mechanical properties to his entities, e.g. size, shape, and arrangement in space, but Berzelius only attributed weights to his proportions (Klein, 1999: 148-149). Klein has argued that this ontological vagueness was crucial in the "uncontroversial" status and success of Berzelian formulae (Klein, 1999: 149).

This lineage of atomistic theory appears rather straightforward but was, of course, much more complicated. Historian of chemistry A. J. Rocke has described Dalton as "opening the floodgates" because no less than nine different forms of chemical atomism were formulated between 1810-1816 (Rocke, 2001b: 2). Also, after the formulation of Berzelius' formalism chemists used a variety of terms, e.g. equivalents or combining weights, some of them eager to distance chemical atomism from atomism in the philosophical tradition (Klein, 2003: 20). Common for the different concepts of chemical atomism is the notion of a chemically indivisible unit which enters into combination with units of other elements. Put differently, *chemical atomism*, as coined by Rocke, is "something plus something", i.e. discontinuous entities not explainable by the "mass, motion, and gravitational forces of the physical atom" (Schütt, 2003: 238-239).

Following Dalton's hypothesis discrete units were made "indisputable" and focus shifted towards finding the correct formula (Bensaude-Vincent & Stengers, 1996: 114). However, theories, formalism, and the traditional analytical method originated in inorganic chemistry. Their application to the organic chemistry was problematic due to experimental and theoretical obstacles.

2.2.3 - From inorganic to organic

Organic chemistry emerged and changed fundamentally during the eighteenth and nineteenth centuries. By early nineteenth century chemists recognized organic chemistry as a specific part of chemistry dealing with substances obtained from animals and plants through various extraction techniques. Animal and plant chemistry was concerned with substances found *outside* the laboratory and 'organic substance' referred to the source of origin: organized bodies of nature. Accordingly organic chemistry and its classifications was placed in a field between natural history and chemistry (Bensaude-Vincent & Stengers, 1996: 43-58; Klein, 2005: 262-263).

Contemporary chemists could also recognize organic chemistry as the traditional method of studying chemical reactions was "extremely rare in organic chemistry" (Klein, 2003: 43). This partly followed from experimental difficulties. Organic analysis was technically difficult as organic substances decomposes easily. In many experiments it was impossible to isolate and identify all the reaction products as demanded by the traditional analytical method (Klein, 1999: 154). Thus chemists like Berzelius doubted the applicability of his formalism to organic compounds. The absence of the traditional method was also based on a theoretical incongruence between organic compounds and the theories of inorganic chemistry. The law of multiple proportions stipulated proportions in *small integers* but organic formulae required large integers (Klein, 2003: 20-22). Despite the challenges Berzelian formulae became important in organic chemistry from the 1820s (Klein, 1999: 150, 154).

Regarding the developments taking place after 1830 I will only address a few relevant developments. According to Berzelius organic chemistry was centered on studying life processes, and occasionally referred to a "life force" (Klein, 2003: 48-49). By 1828 Wöhler artificially prepared ammonium cyanate which transformed into urea, i.e. he synthesized in the laboratory a substance hitherto only known from living organisms (Rocke, 1984: 173; Bensaude-Vincent & Stengers, 1996: 145). Retrospectively this has been made the death blow to vitalism though it was not perceived like that by chemists like Wöhler, Berzelius, or Liebig (Bensaude-Vincent & Stengers 1996: 146; Ramberg, 2000; 173-174).

The event and its use in constructions of a historical myth may indicate a time where organic chemistry could be (re)defined: what belonged to (organic) chemistry? In the 1830s French chemists tried to demarcate their discipline by excluding physiology and anatomy. The French chemist J.-B. Dumas (1800-1884) defined the object of organic chemistry as materials from the "organic kingdom" and its derivatives (Klein, 2003: 67). In order to understand these organic substances European chemists tried to extend the dualist ideas from inorganic chemistry to the organic realm per analogy (Klein, 1999: 159). This was the theory of organic radicals. The radical concept had been in use since the late eighteenth century but instead of simple substances organic radicals were 'compound radicals' and organic compounds were then characterized according to their radical part (Klein, 1999: 159; Partington, 1964: 252).

Towards the 1840s electrochemistry was challenged and ultimately abandoned which marks the transition to the second period of chemistry as divided by Bensaude-Vincent & Stengers

(Bensaude-Vincent & Stengers, 1996: 127). In brief the challenge arose from reactions where electronegative elements like chlorine could substitute for electropositive substances like hydrogen (Rocke, 1984: 195). I now turn to some institutional developments occurring alongside the developments I have just sketched out.

2.2.3 - A national science?

In a brief outline like the one provided here adding nationalities might strengthen the acknowledgement of geographies. However, it might also strengthen a simplified diffusionist view where knowledge emanates from scientific centres like France, Germany, and Sweden. The outline is only intended to provide an overview and for this reason the story is told as if all chemists in Europe was working in unison - as if chemistry was a science detached from geography.

Even though nineteenth century chemistry might undoubtedly be European it was not as uniform as European chemistry implies. Chemistry was European due to the circulation of chemists and theories. Still, it was also "profoundly influenced by national styles" (For European chemistry, see Kragh, 1998b: 329; challenging the 'European' Bensaude-Vincent & Stengers, 1996: 96, the quotation on national styles is on this page).

Zeise's encounter with Parisian chemistry mentioned in (2.1.1) might exemplify both characteristics of nineteenth century chemistry. During his *Wanderjahre* he travelled to Germany and France. However, the trip displayed the quite different stances taken towards atomism in Denmark, Germany and France (Jacobsen, 2006: 752). Likewise, atomic theory was not a singular theoretical system and after the 1830s the three largest European countries adopted different atomic systems (Rocke, 2001b: 3).

The national differences can also be seen in the educational systems. The German system of education was like a counter-model of the French system. The latter was centralized and oriented towards Paris while pre-Bismarck Germany developed in regional, decentralized networks. Still, it generally holds that chemistry experienced a change in status and was increasingly seen as an independent scientific discipline (Bensaude-Vincent & Stengers, 1996: 98, 95).

Until the nineteenth century chemistry had been an auxiliary science to medicine, pharmacy, or geology. In eighteenth century Germany pharmacists acquired chemical knowledge training in shops - textbooks were only read as self-study (Homburg, 1998: 46). During the nineteenth century chemistry became an end in itself and towards the middle of the century it was practiced by hundreds of well educated chemists (Bensaude-Vincent & Stengers, 1996: 95-99).

Chemistry in Copenhagen experienced similar developments. Prior to and in the early nineteenth century chemical training was obtained by apprenticeship in pharmacies before taking pharmaceutical examinations as seen in the biographies of Zeise, Forchhammer, and Scharling. From 1805-22 chemistry was placed under Ørsted's university professorship in physics and in general chemistry lagged behind physics. This was partly due to an "ideology of supremacy of spiritual over manual work" (Kragh, 1998a: 239). Similar discontents towards the mangle of laboratory practice existed in Germany. This changed gradually because of societal demands and from 1810 Stromeyer organized regular laboratory training in analytical chemistry in Göttingen (Homburg, 1998: 58, 53-54). In Denmark laboratory training was established in 1820 (Sylvest, 1972: 17). Both the German and the Danish case of practical laboratory training counters the older standard story naming Liebig's Giessen as the pioneering site of practical university instruction in chemistry (For a newer example of giving Liebig priority, see Rocke, 2001a: 85; countering it Lockemann & Oesper, 1953: 202; Homburg, 1998: 54).

In the biographical sections above I described in the biographies above that Zeise was appointed as the first professor in chemistry at the university of Copenhagen in 1822 and from 1823 Forchhammer joined as associate professor in chemistry (and mineralogy) (see (2.1)). As chemistry was now taught by teachers with chemistry as their sole or main vocation it achieved autonomy from physics. Zeise also took care of the "Övelseslaboratorium"[9] where chemists and other interested in acquiring chemical knowledge could train practical skills. However, the university's laboratories (additional were built and locations changed) were not necessarily used to a large degree. If we are to believe Scharling's short history of chemistry in Denmark, Scharling was often to have been the only one using the facilities in the late 1820s (Scharling, 1857: 76). This changed as practical training in chemistry became a compulsory part of the pharmaceutical education in 1828 - something which Kragh also

[9] "Training laboratory"

describes as an indication of the newly won status of chemistry at the university (Scharling, 1857: 76; Kragh, 1998a: 239).

A final comment regards the Polytechnic college inaugurated in 1829 and the educations related to chemistry. The new Polytechnic College owed much to Ørsted's efforts at establishing it and he became its first director (Kragh et al., 2008: 158). The university of Copenhagen and the Polytechnic college were closely affiliated as science teachers from the university were obliged to lecture at the Polytechnic as well (Nielsen, 2007: 205). Nielsen has described the result of this joint teaching as a unique chemical community in Denmark with an "extremely close" relationship between academic chemists and polytechnical graduates. Also, pharmaceutical students also joined the same lectures and likewise the laboratory (Nielsen, 2007: 205). The lectures intended for polytechnic students and for university students were "practically one and the same" and oriented towards "scientific, pure chemistry" (Nielsen, 2007: 205). The close relationship between pharmacists and chemists may be exemplified by the periodical *Archiv for Pharmacie*[10] launched, edited, and published by S. M. Trier (1804-1894). Though intended for owners of pharmacies it included a "substantial amount of chemistry" as Danish pharmacists were interested in such matters due to their educational background (Nielsen, 2007: 208). As an example it may be noted that Zeise published the introduction for his *Anvisning* in Trier's *Archiv*.

[10] "Archive for Pharmacy"

3 - Textbooks and classifications

In the nineteenth century the quantity of known substances rose significantly. Between 1800-1850 24 new elements were added to the 34 elements known by the time of A.-L. de Lavoisier (1743-1794). This posed a challenge to the system building teachers in chemistry: How to assemble all these elements in textbooks without merely listing them alphabetically (Bertomeu-Sánchez et al., 2002: 228)? In other words, chemists were concerned with assembling the most efficient entry points into an infrastructure in continuous expansion.

In France chemists discussed *natural* and *artificial* classifications as a possible solution. The former were "based on all the characters of the substances to be classified" whereas artificial classification focused on single characters (Bertomeu-Sánchez et al., 2002: 236). The periodic table was perceived within these debates as an artificial system as it organized elements by atomic weights (Bensaude-Vincent & García-Belmar, 2015: 106). Before proceeding to the Danish textbooks I formulate some general points on the connection between textbooks and classifications based on research by Bertomeu-Sánchez et al. (2002) and Garciá-Belmar et al. (2005).

Bertomeu-Sánchez et al. describe two functions system builders wanted their textbooks to fulfill as entry points:

i) Textbooks were to provide an overview of the "material world of chemical substances" as objectively and faithfully as possible.
ii) They must facilitate the learning of their audience.

In France this resulted in discussions of the "order of things", i.e. how to order things taking into account both the knowledge of the elements and the didactically most suitable presentation (Bertomeu-Sánchez, 2002: 229, 243). Again, the periodic table may exemplify classification based on knowledge. The most common example of didactic classification is progression from known to unknown. This was an ideal since before Lavoisier and often in combination with the ideal of simple to complex. The ideal textbooks progressed from simple, known elements to the more complex, unknown compounds (García-Belmar et al., 2005: 233).

Inspired by the French cases I analyze the discussions of classifications in textbooks. I show that both Zeise and Forchhammer were concerned with establishing the best entry points via the ideal of simple to complex. Subsequently, I analyze how textbooks were used to manipulate the gateways between different knowledge infrastructures. I analyze the case of imponderables (heat, light, electricity, and magnetism), and the distinction between organic and inorganic chemistry. Both instances are examples of how textbooks aim at rearranging immaterial aspects of a chemical infrastructure. Either by debating what objects belong to chemistry or the gateways between chemistry and other knowledge infrastructures.

3.1 - Textbooks as entry points

Zeise's 1829 textbook features the most elaborate considerations of chemical classifications. Zeise mentions a variety of classifications, such as metals and metalloids or according to the acidity and alkalinity of substances. He elaborates the most on electrochemistry and it is also the classification he chose for the textbook (Zeise, 1829: 280-294).

Zeise's explanation of electrochemistry proceeds from the empirical electrolysis of water to the general remark that elements have electrical characteristics. Zeise exemplifies with a table listing all the elements by their electrical relations from oxygen to potassium: the former is electropositive in relation to all other elements and the latter electronegative (Zeise, 1829: 282-291). Zeise finds the electrochemical classification the most convenient and the 1829 textbook is organized in two main sections, one for the chemically negative and positive elements respectively. However, Zeise's didactic concerns interferes with this plan for the book from the beginning (Zeise, 1829: 293). I will argue here that his didactic classification is the common simple to complex, or known to unknown.

His textbook didactic is considered in the preface of the 1829 textbook. Textbooks ought to progress so that "det forudgaaende baner Vei for det efterfølgende [...]"[11] (Zeise, 1829: 293, viii-ix). Thus, the first subsection of his textbook deviates from a chemically "rigtigere inddeling"[12] to fulfill his didactic principle and to benefit his teaching (Zeise, 1829: 293).

The advantage of this didactic exposition is that the knowledge presented about elements is brought into use as soon as possible (Zeise, 1829: 293-294). For instance, his first subsection deals with all the constituents of atmospheric air and immediately following the first subsection comes an entry on atmospheric air. This implies that Zeise wanted to proceed from simple elements to complex compounds (Zeise, 1829: 420-429).

[11] "the preceding paves the way for the subsequent"
[12] "more correct classification"

The classificatory criteria informing the sequence of substances his 1829 textbook is explained by supplementing the textbook with his notes for a lecture held in 1843-44. According to a list presented in his lecture the textbook's first four subsections primarily deal with metalloids (Zeise, 1829: xviii; Zeise, 1843-44: 12)[13]. This sequence is employed in the lecture as well. This was a didactic choice as the metal-metalloid-distinction had no "videnskabelig Værd[14]" but was useful to present chemical knowledge (Zeise, 1843-44: 11-12). In other words, the sequence in both his lecture and the 1829 textbook is dictated in part by didactical concerns.

Seemingly Forchhammer also subscribes to an ideal of simple to complex, or rather known to unknown (though it should be remembered that only the *Ledetraad* was published in its entirety). He describes the order in his 1842 textbook as not being a "streng systematisk Orden"[15]. Instead elements are listed as to illuminate each other in the best way possible (Forchhammer, 1842: iii). The best way possible seems to be known to unknown as he introduces water immediately following the two first elements (Forchhammer, 1842: 1-18). This shows how different strategies were made to fulfill similar didactic ideals as Forchhammer's sequence of substances differed from Zeise's. Forchhammer starts by oxygen and hydrogen, and then immediately introduces water. Likewise, atmospheric air is discussed as soon as its constituents have been presented (Forchhammer, 1842: 1-18, 235). In this sense both authors seem intent on proceeding from simple to more complex, and known to unknown.

To remedy the lack of systematic order in his 1842 textbook Forchhammer includes a systematic table of elements and compounds before his text begins. Elements are classified by whether their hydrogen or oxygen compounds are predominately acids or alkalis. Interestingly he systematically orders compounds using radicals as a shorthand. For instance, he lists various compounds by their "atomistiske Sammensætning"[16] using R^2O, i.e. two parts of compound substance R to one part oxygen (Forchhammer, 1842: viii).

[13] (Zeise, 1843-44) is a reference to lecture notes kept at the Royal Danish Library in Copenhagen. Generally, I have referenced all Zeise's archival material like this particular instance. The pagination and dating are stated in the original documents. See the bibliography for full references with box numbers.
[14] "scientific merit"
[15] "strict systematic order"
[16] "atomistic constitution"

Forchhammer's *Ledetraad* includes a minor remark on electrochemical classification. Forchhammer proceeds from electrolysis, like Zeise, to introduce the concepts of electropositive and -negative substances (Forchhammer, 1830-31b: 195-202). He concludes, however, that the electrical relation between substances does not depend on "nogen absolut Egenskab"[17]. Thus, one cannot classify substances by electrochemical relations (Forchhammer, 1830-31b: 198). In other words, as an artificial classification electrochemistry is insufficient.

3.2 - Organizing gateways

I now turn to the question of gateways between chemistry and other knowledge infrastructures. I described in section (1.3.1) how disciplines may be understood as networks based on Nye's definitions. I follow this here and analyze how textbooks manipulate the gateways of chemistry with respect to imponderabilia and organic chemistry.

3.2.1 - Imponderables

The question of imponderables showcases possible inclusions or exclusions of observations into chemistry: did chemistry engage in the study of imponderables or did these phenomena belong to physics?

Ørsted had included these phenomena in courses on chemical physics and chemistry, though not conceiving them as imponderables (Kragh, 2005: 321; Jacobsen, 2006: 753). Zeise considered them to be imponderables and included them in his 1829 textbook. However, he questioned their inclusion and claimed to include them only to raise the knowledge of physics in the audience of pharmacists (Zeise, 1829: x). In other words, imponderables was a matter for physics. His inclusion might also be informed by the works he read writing the textbook. Zeise mentions Berzelius' *Lehrbuch* and L. Gmelin's (1788-1853) *Handbuch der Theoretischen Chemie* (1817). The latter organized chemical knowledge according to imponderable (light, heat, electricity) and ponderable (inorganic, organic) substances (Zeise, 1829: xv; Habashi, 2009: 31)[18].

Imponderables are also excluded from chemistry in the books by Scharling and Forchhammer. In Scharling's translations they are simply passed in silence (Scharling, 1837;

---

[17] "any absolute property"
[18] The third edition published in 1827 also distinguished chemistry of the "wägbaren" and "unwägbaren" substances, i.e. ponderable and imponderable substances (Gmelin, 1827: xi).

1841). Likewise, Forchhammer does not include them apart from minor general remarks on the nature of the flame (where the question of imponderabilia is not brought up) (on flames see Forchhammer, 1830-31b: 17; 1842: 166-168; otherwise Forchhammer, 1830-31a; 1830-31b; 1831a; 1831b; 1834-35; 1842).

Silently ignoring imponderables may be read as active attempts at reconsidering the immaterial infrastructure of chemistry, how to demarcate it, and what phenomena to include. I interpret the textbooks to be active factors attempting to shift the infrastructure because later editions of Wöhler's *Grundriss* were translated into Danish (Groth 1854; 1855). Wöhler's new preface for the inorganic textbook is translated and it explicitly excluded imponderables from the chemistry of substances (Groth, 1854: 1). In other words, the 1830s-40s textbooks are not only indicating a body of accepted theory, they are factors trying to (re)construct it by dismantling gateways to other knowledge infrastructures.

3.2.2 - Organic Chemistry

Organic chemistry is, as noted in the historical overview, the origin of a great disciplinary myth. According to legend Wöhler refuted the existence of a life force in 1828. Accordingly the classificatory divide between organic and inorganic is interesting as it is ontological. However, the divide is also interesting as Zeise explicitly debates the relation of chemistry to physiology.

By the 1830s distinguishing organic and inorganic was not a given in textbooks. Wöhler had tried to integrate organic chemistry into his inorganic textbook - and found it theoretically possible. However, in an instructional system such a theoretical approach is "unyttig og selv skadelig"[19] to the student. Scharling's translation thus divides chemistry into organic and inorganic (Scharling, 1837: iv-v).

The organic substances are defined as the result of the life processes of animals and plants. Substances are divided into plant and animal substances by importing classifications from natural history and physiology. Generally, organic bodies are defined as made from carbon, hydrogen, oxygen, and nitrogen. However, they are under the influence of a "livskraft"[20] (Scharling, 1841: 1).

[19] "futile and even harmful"
[20] "life force"

Forchhammer's *Ledetraad* features the most explicit discussion of a life force. Rhetorically he questions the divide between organic and inorganic substances by reference to the general laws of nature. If they govern the substances they must rule in the volcano as well as in the oak. But anyone who studies nature "uden forudfattet Mening"[21] will perceive the forces of animals and plants which are different from those found in a laboratory and mineral chemistry (Forchhammer, 1831a: 3-4). Due to an "organisk Kraft"[22] elements combine in compounds chemists cannot produce and which naturally only occurs in organisms. These are the compounds with which organic chemistry is concerned (Forchhammer, 1831a: 4). Forchhammer also imports classifications from natural history and organizes his section on animal chemistry by physiological principles. The reason was didactical because the physiological principles provided the "letteste Overblik"[23] (Forchhammer, 1831a: 43).

Forchhammer's and Scharling's textbooks indicate that the notion of a life force was still present in Danish chemistry after Wöhler's synthesis. But by the 1840s Zeise's *Haandbog* on organic chemistry would challenge both the life force and the gateway between physiology and chemistry.

Zeise's 1847 *Haandbog* does not discuss life forces. Zeise describes how natural organic substances are almost exclusively known from the activity in "de levende organiske Legemer, som medføre at de leve"[24] (Zeise, 1847: 1, 17). He briefly notes how organic substances cannot be synthesized from their constituents and describes the object of organic chemistry as compounds from the animal and plant kingdom. These compounds, he defines, are predominately carbon compounds (Zeise, 1847: 1). In other words, Zeise's reference to living organisms seems less like an ontological claim of a life force than information on the substance's origin.

The *Haandbog*'s introduction also manipulates the gateway between organic chemistry and physiology. Proper organic chemistry is not concerned with the function of organic substances *in* living organisms - this belongs to physiology (Zeise, 1847: 36). In other words, only the chemical constituents of organisms are allowed passage through the gateway between physiology and chemistry. Furthermore, the physiological distinction between

[21] "without preconceptions"
[22] "organic force"
[23] "most convenient overview"
[24] "the living, organic bodies causing them to live"

animals and plants is of no use in organic chemistry (in contrast to its use by Forchhammer and Scharling). To Zeise there is no evidence that organic substances isolated from their organism are fundamentally different from mineral substances. Thus, chemists ought to explain organic substances following the idea that organic substances are chemically analogous to the mineral compounds (Zeise, 1847: 5).

Not only did the *Haandbog* try to define what substances where allowed to pass between knowledge infrastructures. Zeise also tried to install a hierarchy between them with a unidirectional gateway for theories or knowledge: *from* chemistry *to* physiology. The *Haandbog* claims that organic chemistry can be studied without being connected to physiology. Physiology, however, cannot be studied thoroughly without insights from organic chemistry (Zeise, 1847: 36). Put differently, Zeise claims that physiology is depending on knowledge imported from chemistry but not vice versa.

3.3 - Conclusion: Classifications and textbooks

The analysis above presents different relations between classifications and textbooks in two ways.

i) I have described how the classifications in textbooks was not solely a scientific matter. Classifications and textbooks included didactical concerns.
ii) I have analyzed the attempted manipulations of gateways.

I have showed that both Zeise and Forchhammer, as system builders, adhered to a didactic ideal of progression from known to unknown or from simple to complex. Both authors encountered difficulties because the more familiar substances, e.g. atmospheric air and water, are not chemically simple. Of course, these difficulties were not only encountered by Danish chemists (for other instances, see Bertomeu-Sánchez et al., 2002: 232). Thus, the different sequences employed by Forchhammer and Zeise can be considered solutions to the same classificatory ideal. They simply introduced the known substances as soon as possible.

Analyzed as system builders, they were concerned with establishing the most useful entry point into chemistry. Establishing entry points, of course, included organic chemistry. Wöhler retained a distinction between organic and inorganic (as did Scharling) and Forchhammer explicitly based his use of physiological classifications on the didactical benefits it provided. Even though both Scharling and Forchhammer introduced the concept of a life force neither discussed it in any of their entries on organic substances. This suggests that in fact the notion of a life force was not central to the knowledge available of these substances.

In contrast to Forchhammer and Scharling, Zeise explicitly questioned the relevance of physiology to organic chemistry in his *Haandbog*. I interpret Zeise's rejection as arguing for the independence and autonomy of chemistry. In the local infrastructure of chemistry at the institutions in Copenhagen this meant questioning the relevance of imponderables to the teaching of chemistry and cutting the links to physiological principles to gain independence.

Infrastructures develop and change gradually as they are not controlled from one centre. Edwards dubs this the *inertia* of infrastructures. In the analysis provided above inertia helps explain why Zeise's rearrangement of the immaterial infrastructure, i.e. his gateway manipulation, could not be instantaneously successful. He was not the only teacher of chemistry or the only textbook author, and accordingly he was not in full control of the infrastructure. The same goes for the case of imponderabilia: the exclusion of these phenomena from chemistry was gradual and textbooks was put to action in the reworking of gateways during the 1830s-50s.

This section (3) has displayed instances where textbooks actively renegotiated the infrastructure, e.g. by reworking existing gateways. Furthermore, the presentations of the relations to other knowledge infrastructures could also form or inform the audiences understanding of the disciplinary landscape. In this sense Zeise's discussion of priority with regards to physiology is not unimportant. The next section (4) is more concerned with the organization of the chemical infrastructure itself.

4 - Textbooks and theories

Textbooks are the entry points into knowledge infrastructures like chemistry. Remembering Bertomeu-Sánchez et al.'s remarks in section (3) textbooks have two fundamental functions: providing an overview of chemistry and the way chemistry sees the world, and facilitating the learning process of the intended audience (Bertomeu-Sánchez et al., 2002: 229). My theoretical framework describes scientific disciplines as knowledge infrastructures comprised of specific theories, standardized vocabulary, and shared ideals (when focusing on immaterial aspects of the infrastructure) (Edwards, 2010: 17-18; Nye, 1993: 274). Textbooks, then, are interesting as texts where authors try to assemble and organize a specific presentation of the chemical knowledge infrastructure. Textbooks and their presentations of chemistry are intended to *inform* students with knowledge and practical rules of chemistry, e.g. vocabulary. However, they are also to *form* students to comply with norms of the knowledge infrastructure.

This section analyzes how centrally atomism as a theory was placed in the infrastructure of chemistry and what knowledge, or norms, were presented as central junctions in the network based on the textbooks by Zeise, Forchhammer, and Scharling.

In one sense this section reads textbooks as indicating the organization of knowledge infrastructures. What was considered the central junctions which other parts of the network oriented itself towards? However, the textbooks are arguably also active in a twofold sense. Firstly, they are *formative* entry points requiring aspiring chemists to behave in a specific way or adhere to standardized ideals of practice. Secondly, being written in the early years of chemistry as an autonomous university discipline the ideals and theories presented in textbooks also serve to establish or consolidate an infrastructure for academic chemistry. Thus, the following analysis also considers how textbook contributes to a self-image of chemistry.

In a Swedish context Lundgren has shown how atomism was not delegated a central position in nineteenth century chemistry as presented by textbooks. Rather, textbooks established - knowingly or not - empirical work with an instrumental approach to theory as the central junction of chemistry. Instrumentalism was not a "conscious philosophical standpoint" but the opinion expressed in textbooks that theories "had to follow from facts" and the chemists' most important task was searching for facts (Lundgren, 2000: 93, 96, 108). Theories of atomism were not presented as required for the practice of chemistry but most of the books practiced a "common-sense" atomism similar to chemical atomism. Atoms were simply definite proportions of combining substances (Lundgren, 2000: 96).

In order to analyze the infrastructure of chemistry, and atomism's place in it, I follow Lundgren who suggests focusing on the sequence of arguments in textbooks. In general Swedish textbooks on chemistry would open with a theoretical chapter discussing atomism before the "sometimes overwhelmingly descriptive sections" where atomism did not play a central role. Technically oriented books, by contrast, would only include theory after specific instructions, i.e. theory was not necessary for the practical advice given (Lundgren, 2006: 767). This shows the importance of textbooks' structural features in both indicate and actively present the infrastructure of chemistry as oriented towards empiricism rather than theories of atoms.

Below I describe similarities between Lundgren's findings and the Danish textbooks. Most of the textbooks have a common-sense atomism in descriptions of chemical reactions. That is, they describe reactions in terms of "Dele", "Grunddele", "Maal", or "Værdier"[25] of given elements that combine like building blocks. However, all the textbooks emphasizes experience and empirical observation as the central junction, whereas theoretical considerations on atomicity is placed at the outskirts of the immaterial infrastructure of chemistry.

4.1 - Symbolism as a shorthand

Atomism is the one instance where Scharling explicitly states a deviation from Wöhler's original. Where the original uses atomic numbers, weights, atoms, or similar terms Scharling substitutes with "**Værdital** og **Værdier**"[26] for didactic reasons (Scharling, 1837: vii). These terms are more comprehendible to the beginner in chemistry in terms of meaning and use, and Scharling added a small section to elaborate on the meaning of the more common notions of equivalents and atoms (Scharling, 1837: vii-viii).

The inorganic textbook indicates a stance towards atoms as peripheral to chemistry. It opens with an empirical definition of "Grundstoffer"[27] as substances which by no means can be split

[25] "Parts", "fundamental parts", "Measures", or "Amounts"
[26] "numbers of amounts and amounts", bold letters indicate spacing as emphasis in the original text.
[27] "Elements"

into other constituents. Curiously the definition of atoms - given on the same page - is not the same as the elements. Atoms are the innumerable, miniscule *Dele* that "man tænke sig"[28] constituting the mass of bodies (Scharling, 1837: 1). In other words, atoms are hypothetical and not central to the concept of elements. This is evident as the entire group of metalloids (counting 12 elements) is explained without atoms using *Dele* or *Maal* instead (Scharling, 1837: 2-23).

When the textbook elaborates on atomism it is derived empirically and represented as a convenient way of expressing elements and compounds in a "kort og simpel Maade"[29] (Scharling, 1837: 24-26). The argument starts with the empirical observation that weights of elements in reactions display fixed proportions (if one substance, in this case oxygen, is taken as unity). A table of *Værdital* is provided and an example in deciphering it: if silver unites with sulphur, then exactly 201 *Dele* sulphur combine with 1351 *Dele* silver (see appendix A for the table). The weight relations are fixed and any superfluous silver or sulphur will not take part in the combination (Scharling, 1837: 25). Now, the numbers in the table may be called atoms, equivalents, proportionate numbers or *Værdital*. This vocabulary is convenient as one is free from stating 1351 *Dele* silver and can simply state one "Atom, Æqvivalent, eller Værdi"[30] of the element in question (Scharling, 1837: 26). Despite this pragmatic approach to vocabulary Scharling refused to retain the concept of atoms as used in the German original of his textbook.

Without mentioning Berzelius his symbolism is introduced and described terms of functionality. In order to present the composition of compounds in a "kort og overskuelig Maade"[31] each element is attributed a sign which merely expresses its *Værdi* (Scharling, 1837: 26-31). Whereas the sections on individual elements and their compounds in both the inorganic and organic textbooks does not use the terminology of atoms (instead they use *Dele* or *Værdier*), Berzelian symbolism is used (see, e.g. Scharling, 1837: 209-207; Scharling, 1841: 39). Berzelius is mentioned both in Wöhler's preface and in Scharling's added section. Wöhler describes the textbook as an excerpt of Berzelius' *Lehrbuch* which Wöhler translated into German (Scharling, 1837: iv; Blondel-Mégrelis, 2000: 233-234). Scharling's added

[28] "one imagines"
[29] "short and simple way"
[30] "Atom, Equivalent or amount"
[31] "short and comprehensible manner"

section just mentions that the textbook follows the assumptions of Berzelius in how to calculate and understand the *Værdital* (Scharling, 1837: 34).

In general Scharling's added section to the translation states nothing novel but stresses empirical experience more than Wöhler's description of atomism. In the added section the definite proportions have been shown by "Erfaringen"[32] and the proportions in chemical combinations are simply the atomic numbers, equivalents, etc. (Scharling, 1837: 32-33).

In the chemical infrastructure sketched by Scharling's translation empirical observation is the central junction. The simple elements are defined as the empirically indivisible substances and *Erfaring* forms the basis of the theoretical considerations. The inorganic textbook does not imply the terminology of atoms to be central in the study of chemistry. Rather, Scharling substituted the occurrences of atoms from the body of the text and as a result atoms are discussed primarily in the short 11 page chapter introducing *Værdital* and definite proportions (compared to the total 207 pages in the inorganic textbook and 163 pages in the organic (Scharling, 1837; 1841)). The structure of the inorganic textbook does not fit perfectly with Lundgren's generalization that textbooks would open with remarks on atomism and then not use it in their main text. The latter holds true, but the introduction of atomism is postponed until after the section on metalloids which, however, allows Wöhler to define them as the outcome of empirical observations.

The next section is on Forchhammer. I show that he initially distanced himself more explicitly from the concept of atoms and generally stressed the importance of empirical observation.

4.2 - Atomism as derived from experience

Forchhammer's three textbooks largely overlap each other in terms of elaborations on atomism and likewise the organization of the chemical network presented: empirical observations are the central junction of the chemical infrastructure. Theory, like atomism, is derived from the available observations. Forchhamer's *Ledetraad*, written for the Military Academy, resembles Lundgren's characterization of technical textbooks providing practical advice rather than theory. The *Ledetraad* specified its audience in its title but Forchhammer's later textbooks do not. Interestingly, the *Ledetraad*'s section on atomism is reprinted in the later 1834-35 and 1842 textbooks though in a rewritten form with changes in argumentation

[32] "experience"

indicating that changing audiences caused a revision of the theoretical considerations. In general, however, chemistry is still represented as an infrastructure centred around empirical observations.

In the following I elaborate more in depth on the argument presented in the *Ledetraad* and then analyze the changes made in the 1834-35 and 1842 textbook.

4.2.1 - Theory as a guiding principle

In congruence with Lundgren's description of technically oriented textbooks the *Ledetraad* does not open with a section on atomism. Such a section is postponed until the opening of the first volume's second part, i.e. more than 100 pages into the development of inorganic chemistry (Forchhammer, 1830-31b: 7-14).

Atomism is derived as a purely empirical observation on the basis of oxalic acid. Forchhammer starts by introducing a concept of equivalents in neutral solutions. He describes how experiments show that fixed amounts of different acids may substitute each other in neutral solutions without affecting the neutrality (Forchhammer, 1830-31b: 9-10). The argument continues that these observations of equivalents could be expanded to encompass the elements. Taking oxygen as 100 it is possible to calculate numbers of proportions for all the elements. The proportions, Forchhammer stresses, are contingent as they are found by experiment. Thus, they are open to change due to precise experiments or if something other than oxygen was chosen as unity. Choosing oxygen as unity is motivated by convenience because oxygen often participates in reactions: it is more convenient to calculate with 100 than a more irregular value (Forchhammer, 1830-31b: 11). In other words, proportions are introduced as empirical facts and the theoretical descriptions are pragmatically based on convenience. Forchhammer mentions that some chemists have been led by the approximate relation of 1:8 between hydrogen and oxygen to assume that all the numbers of elements are products hydrogen's number multiplied with integers. But Forchhammer dismisses this assumption as insufficiently substantiated by experience (Forchhammer, 1830-31b: 11).

Forchhammer continues the introduction of atomism stating that so far his "Resultater [er] ligefrem udlede af Erfaringen"[33]. However, to ease the presentation one seeks "Tilflugt"[34] in theoretical assumptions. These assumptions are the existence of indivisible, small *Dele* called

[33] "results [are] directly deduced from experience"
[34] "refuge"

"Grunddele" or with a "fremme[d], mindre rigtigt Udtryk, Atomer"[35] (Forchhammer, 1830-31b: 11). Forchhammer introduces theoretical assumptions as a convenient tool for the exposition of knowledge and clearly distances himself from the concept of atoms. Forchhammer states that these theoretical assumptions are something chemists "forestiller sig"[36], i.e. atoms or *Grunddele* are hypothetical concepts (Forchhammer, 1830-31b: 11)

Berzelian symbolism is introduced without mentioning Berzelius and Forchhammer provides a rhetorical defense of what he characterizes as the hypothetical and cumbersome way of describing chemical composition following from atomic theory and symbolism. The answer is worth quoting at length:

> thi denne Betragtning og dens Resultater ere Ledetraadene, der føre igiennem de utallige mange chemiske Forbindelser; det er denne Betragtning , som leder os lige til Maalet, hvilket man ellers ikkun var i Stand til at naae ved møisommelige Forsøg.[37] (Forchhammer, 1830-31b: 14)

In the quotation Forchhammer describes theory as a heuristic device for the chemist. Furthermore, atomism and its related symbolism is a matter of efficiency and avoiding laborious experiments. The latter is substantiated by an example from gunpowder production. Forchhammer describes how huge amounts of gunpowder could have been saved using the new theories to determine the best mixture instead of discovering it empirically (Forchhammer, 1830-31a: 14). In other words, theories may be very useful but regarding the question of atoms it is the empirical foundation which is considered central to the chemical infrastructure.

The last point to be made with regards to the *Ledetraad* is the didactic use of chemical atomism. While distancing himself from the concept of atoms the *Ledetraad* does employ Berzelian symbolism and its didactical schemata explaining reaction processes can be interpreted as founded on chemical atomism. These schemata are interesting as Forchhammer's textbooks are the only studied here using them. I have no evidence of their origin though the historian of chemistry B. Haupt has described similar schemata in the 1830s Germany. In the German instance the schemata continue an older tradition of affinity tables (Haupt, 1987: 237).

[35] "Fundamental parts" and "foreign and less correct expression, atoms"
[36] "imagines"
[37] "this view and its results are the guiding principles leading through the innumerable chemical combinations; it is this view which guides us straight to the goal otherwise only attainable through laborious experiments"

The *Ledetraad* is the only textbook analyzed for this thesis describing gunpowder at length and the description may exemplify Forchhammer's didactic use of chemical atomism. His description of gunpowder is aided by a sort of flowchart schemata of the reaction processes (see appendix B and Forchhammer, 1830-31b: 181). Such a schemata presents the reader with the elements reacting and employs lines and brackets to indicate what substances recombine like building blocks in terms of *Grunddele*.

These schemata are employed in all Forchhammer's textbooks and provide overview of reactions in varying detail. Some simply state names like oxygen and chloride while others specify the weights of substances in the reaction (compare appendix C, illustration 1, 2, and 3). This also shows that he did not utilize the full potential of Berzelian formulae. If Forchhammer had done so, he could merely have stated the Berzelian symbol of substances implying both name and weight. Nonetheless, Forchhammer's textbooks describe reactions in a way which may be subsumed under chemical atomism: observing discrete units which enter into combination with each other (see section (2.2.2)).

In the unfinished textbook from 1834-35 Forchhammer describes an important feature of these didactic schemata: they are not exhaustive. In the case of oxalic acid he describes how the schemata does not display all the products occurring in the reaction but only the ones present in the largest quantities (Forchhammer, 1834-35: 127). In other words, the didactic schemata are representations aiding the comprehension of reactions by simplifying them.

4.2.2 - The textbooks from 1834-35 and 1842

The unfinished 1834-35 textbook reprints most of the *Ledetraad*'s section on atomism (Forchhammer, 1834-35: 126-139). In this unfinished textbook atomism is introduced 130 pages into the 192 page book. Before introducing atomism the textbook already describes elements and compounds using Berzelian symbolism and the vocabulary of *Dele* (e.g. Forchhammer, 1834-35: 76). The outline of the argument for atomism is practically the same as in the *Ledetraad*. The only noticeable definition added is the atomistic nature of the *Grunddele*-concept. Forchhammer discusses two possible formulae of a chrome-compound: either 1 *Grunddel* metal and 1½ *Grunddel* oxygen or 2 metal to 3 oxygen. The former hypothesis, he concludes, cannot be made since one cannot assume half *Grunddele* (Forchhammer, 1834-35: 137). The 1834-35 textbook retains the rhetorical defense of atomism with its symbolism as a guiding principle including the argument on the basis of gunpowder production (Forchhammer, 1834-35: 138). Since the 1834-35 textbook does not otherwise discuss gunpowder this example appears to be a textual remain of the *Ledetraad*.

Forchhammer's 1842 textbook omits the rhetorical defense of atomism but otherwise reprints most of the section on atomism though with some changes (Forchhammer, 1842: 171-192). In this sense the 1842 textbook indicates some significant changes in Forchhammer's presentation of atomism. First of all, atoms are no longer presented as less correct than *Grunddele* though the term atom is still not used generally in the work (Forchhammer, 1842: 180). Secondly, the vocabulary and theory was no longer in need of a practical application to defend its inclusion in a chemical textbook.

Furthermore, the definite proportions of oxygen and hydrogen in water are now phrased as *Æqvivalenter* and the numbers describing these are "Æqvivalenttallene"[38] (Forchhammer 1842: 178). This is important as Forchhammer distinguishes equivalents and atomic weights. He exemplifies with hydrogen where it takes two *Maal* to give one equivalent of hydrogen, i.e. when hydrogen combines with substances like oxygen it requires two *Maal* equal to 6,24 to give one *Æqvivalent* of 12,48 (Forchhammer, 1842: 180-181).

One last significant change is the status of hydrogen as unity for calculating proportions. In the former two textbooks it has been an insufficiently substantiated hypothesis but in the 1842 textbook the hypothesis is noted for having gained recognition (Forchhammer, 1842: 179). At the end of the 1842 textbook Forchhammer discusses atomism again and argues for taking hydrogen as unity in calculations of proportions rather than oxygen (Forchahmmer, 1842: 452).

Once again empirical observations take the role of central junctions in Forchhammer's presentation of chemistry. He gives priority to empirical observations over theory as empirical results should be the judge of theory choice. Considering hydrogen = 1, he claims, has been rejected by chemists due to a lack of agreement with the results of immediate experience. Furthermore, chemists have argued that there is no "theoretisk Grund"[39] for using hydrogen as a common divisor. Forchhammer refutes this by addressing a similar lack of theoretical explanation for the necessity of definite proportions. Atomic theory does not explain this necessity because atomic theory is "hverken [...] mere eller mindre end et almindeligt Udtryk

[38] "Equivalent numbers"
[39] "Theoretical reason"

for Erfaringen"[40]. Thus, Forchhammer concludes, everything must follow from the verdict of empirical observations. These favour considering the weight of hydrogen as the "communis divisor"[41] for the weight of other elements (Forchhammer, 1842: 452). This part of the 1842 textbook is interesting because it communicates a norm of evaluating theory entirely on the basis of empirical observations. In addition, it shows how textbooks not only indicates accepted knowledge but take part in discussions of theories and results, e.g. whether oxygen or hydrogen is the best unity in calculations.

Summing up, Forchhammer's textbooks derive definite proportions empirically before introducing atomism as a theoretical assumption. Theories, in the rhetorical defense, are guiding principles for the chemists and a way of avoiding laborious experiments. Despite this instrumental understanding of theories it was important initially that *Grunddele* was used rather than *Atomer*.

Considering the textbooks by both Forchhammer and Schaling as entry points into the chemical infrastructure two things may be observed. First of all, empirical observations are beyond doubt the central junction seen both from the many facts listed on substances in the descriptive sections and in the derivations of atomism. Though not completely like Lundgren's generalizations I still interpret the structures foud in the Danish textbooks as supporting empirical ideals as the central junction. For instance, both derive atomism empirically and keeps it in confined sections of their textbooks. Secondly, Atoms as such are generally dismissed but Berzelian symbolism and the definite proportions are obligatory passage points in the infrastructure for the aspiring chemist, i.e. this symbolism *had* to be learned to become a chemist but atoms were less inevitable.

4.3 - Zeise's idealized chemist

Zeise's textbooks fit rather well into the picture of the chemical infrastructure and the role of atomic theory presented by Forchhammer and Scharling. Zeise's textbooks focus on empirical observations and despite introducing the idea of atomism it is not employed to a large extent. Thus, I focus more on the self-image of the *eminent chemist* Zeise is assembling. I conclude this section on textbooks and theories by briefly considering the compatibility of Zeise's ideal with the way Forchhammer and Scharling presents chemistry, i.e. to suggest if their textbooks

[40] "Neither more nor less than a general expression for the experience"
[41] "Common divisor"

contributed to the inertia of the same infrastructure of chemistry or whether their textbooks were made to shift the infrastructure in different directions.

4.3.1 - Atoms and Fundamental Atoms

Zeise, like the other chemists, stresses empiricism and the hypothetical nature of atomism in his 1829 textbook. For instance, the "forestilling"[42] of simple elements is based on our inability to subdivide them further. This is of course contingent and Zeise concludes with a general requirement: "Our" ideas must comply with the available *Erfaringer* and this is a general rule in "Naturlæren"[43](Zeise, 1829: 281). The use of "our" is a discursive tool for including the audience in the group of scientists, that is, *we* are the sort of people who comply to these specific norms.

To return to the matter of atoms, Zeise's definition of simple elements is not linked by necessity to that of atoms (they are separated by eight paragraphs) similarly to Scharling (Zeise, 1829: 291-292). Atomism is discussed in merely one page of the +860 page textbook. Zeise explains that various *Erfaringer* have led to the idea of indivisible units which cannot be sensed dubbed "**Atomer eller Grunddele**"[44]. Also, that individual elements have definite weights and chemical combinations are formed from *Grunddele* (Zeise, 1829: 291). Zeise exemplifies with combinations of oxygen and sulphur. However, in the body of his text, i.e. the sections actually describing the properties of individual elements, the description of sulphuric oxides is provided without using the vocabulary of *Grunddele* or atoms all together (Zeise, 1829: 292, 358-375). This implies that atoms was not to be regarded central to the chemical knowledge provided.

Zeise's 1847 *Haandbog* on organic chemistry is a fine example of how the mere use of the concept of atom does not entail atomicity in the sense we presently understand it. The *Haandbog* describes substances with "Grundatomer" and "Atomer"[45]. The former designates singular elements and the latter compounds like cane sugar. That is, one atom of cane sugar is $C^{12}H^{20}O^{10}$ and consists of 42 *Grundatomer* (Zeise, 1847: 4). The *Haandbog* does not elaborate on what atoms are and the vocabulary seems to represent the radical theory. Radicals are introduced after listing compound substances which behaves like singular units

[42] "idea"
[43] "Natural philosophy"
[44] "Atoms or Fundamental parts". Bold letters signify spacing in the printed text.
[45] "Fundamental atoms" and "Atoms"

in forming chlorides or oxides. Zeise concludes that chemists are "beføiede"[46] in assuming the existence of compound radicals (Zeise, 1847: 5). This again shows, how priority is placed on empirical observations. Experience is the actual judge deciding what theoretical choices are allowed.

4.3.2 - The eminent chemist

Zeise definitely tried to center the chemical infrastructure around empirical observations and practical, concrete work. In the notes for a lecture he declares that "Al ægte Chemie"[47] is, in a certain sense, practical. Chemistry is built upon the art of obtaining chemical experiences, i.e. experiments (Zeise, 1843-44: 9). In other words, all of chemistry is centered around the acquisition of empirical facts by experiments and - as noted above - the general rule of natural philosophy was for our ideas to comply with the empirical experience.

Similar ideals oriented towards empirical work are central to Zeise's characterization of the "fortrinlige chemiske Forsker"[48] given in the *Anvisning*, his unfinished 1840s textbook project (Zeise, 1844: 5). Theorizing are not among the eminent chemist's skills. Rather, chemistry requires gifts and abilities like sharp and well trained senses, "behændighed"[49], and a suited "Aand og Sind"[50] (Zeise, 1844: 5). The chemist approaches the empirical work without any preconceptions and with a meticulous awareness towards the relevant phenomena. Endowed with these the chemist is able to chose the shortest and most certain route to improving chemistry (Zeise, 1844: 5). Zeise actively tried to establish these norms or requirements centrally in the chemical infrastructure during the early 1840s. He presented the norms in his textbook project and likewise in his lectures from the 1840s (see Zeise, 1841-42b, 5-7; 1843, 12).

Zeise was also using his textbooks to legitimize chemistry as an independent science. The *Anvisning* describes the eminent chemist as spurred on and guided by the desire of "forøget, selverhvervet indsigt"[51] and the delight which accompanies such efforts (Zeise, 1844: 5). Chemistry is studied for its own sake, for the acquisition of knowledge and to a lesser extent for the benefits of its application (Zeise, 1844: 3-4). The chemist was presented as a rather

[46] "justified"
[47] " all proper chemistry"
[48] "the eminent chemical researcher"
[49] "agility"
[50] "spirit and mind"
[51] "increased self-acquired knowledge"

marvelous figure. Besides the many traits just listed, the chemist revealed, through experiments, a world which greatly surpassed the one provided by our senses in diversity. Furthermore, chemists would encounter a variety of difficulties and even "Farer for Liv og Sundhed"[52] in their work (Zeise, 1844: 3-4). Again, Zeise had lectured the same celebration of the chemist. One lecture even added that chemists probably struggles with more threats to their life and well-being than any other "Naturforsker"[53] (Zeise, 1841-42b: 2-4)

Returning to the legitimization strategy, it is elaborated in the *Haandbog*. Here chemistry is linked to science more generally as both are driven by the "aandelige Trang til og Glæde over"[54] new knowledge (Zeise, 1847: 36-37). In the attempts at legitimizing chemistry by demarcating it from more application oriented disciplines Zeise's textbooks are also indicators of a broader change in the history of Danish science. In the first fifty years of the nineteenth century the focus on application faded in favor of a new "empirical ideal" where scientific knowledge was considered as intrinsically valuable (Kragh, 2005: 450). This shift in legitimization is seen in Zeise's lectures and his textbooks. Chemistry is presented as a true science requiring not only gifts and skills but courage!

4.4 - Conclusion: Empirical observation at the center

Zeise's elaborate description of the eminent chemist contains a variety of ideals and considerations not present in Forchhammer's and Scharling's textbooks. Zeise's didactic activities, i.e. his lectures and textbooks, ought not to be read merely as *indications* on what the norm *was*. His work likewise appear as assertions regarding what they *should be*. I noted how the (re)definition of chemistry as a science whose knowledge had intrinsic value was part of a broader shift of legitimization. Actually the same shift is hinted at by Forchhammer and Scharling. Forchhammer's 1842 textbook states a primary focus on "Naturens store Huusholdning"[55] in the substances discussed. Likewise, Wöhler's preface to the inorganic textbook describes how the teaching of chemistry must not solely have a practical agenda.

[52] "Threats to one's life and well-being".
[53] "natural scientist"
[54] "spiritual need for and delight in"
[55] "The great economy of Nature". Economy here taken in its etymological sense of *Oikonomia*.

Chemistry must also be considered a "Dannelsesmiddel for Tænkeevnen"[56]. In this sense, Forchhammer's and Scharling's textbook also add to this (re)definition of chemistry's purpose.

All their textbooks agree that chemistry is a discipline whose infrastructure has empirical observations and work as the central junction. Thus, they seem to be adding to the same infrastructure centered on *Erfaringer*. *Erfaringer* are what chemists ought to seek and *erfaringer* are the actual basis for the atomism and vocabulary introduced.

Atomism as a ontological question was delegated a peripheral position in comparison to the centrality of chemical atomism and Berzelian symbolism. The latter two are generally included in the books and not questioned as they represented empirical observations and practical, convenient tools for describing compounds or didactically representing chemical knowledge. The textbooks may thus be read as *informative* and *formative* entry points. They informed readers on the known substances, their definite proportions, and the vocabulary used by chemists to describe these. Likewise, they sought to form readers by presenting them with requirements and ideals, e.g. the centrality of empiricism.

However, in the words of Lundgren, there was more to teaching chemistry than "consulting and studying textbooks" (Lundgren, 2000: 93). There is a practical dimension of laboratory training to which I turn in the final empirical section.

[56] "Means for educating the faculty of thought". Though, "dannelse-" is probably closer related to the German notion *Bildung*.

5. Textbooks and laboratories

Laboratories are central to our present day understanding of chemistry and chemical work. Within science studies laboratories have for long been analyzed as the coordinated work of heterogeneous elements like humans, instruments, and texts (Law, 1986; Callon et al., 2011). As such, laboratories may be analyzed as networks. Keeping my theoretical approach of infrastructures in mind I emphasize here that the following analysis focuses on a specific level of the infrastructure of chemistry. Infrastructures consists of linked, heterogeneous networks of theories, people, physical facilities etc. (see section (1.3)) Here, I analyze how textbooks may function in the specific material network of a training laboratory.

We would probably take for granted that teaching institutions have training laboratories, i.e. laboratories where students acquire the necessary laboratory skills. However, in the eighteenth and nineteenth centuries natural philosophy was mainly taught through lectures accompanied by lecture demonstrations (García-Belmar & Bertomeu-Sánchez, 2015: 599). When laboratories intended for training emerged, actors, e.g. teachers or mentors, had to organize and coordinate these new networks of students, objects, and instructions as to facilitate student's learning. Eventually, as described by Knight, laboratories provided the apparatus, equipment, and "the controlled environment in which to use it" (Knight, 2009: 149). This section analyzes how the Danish textbooks could serve as integrated elements of training laboratories, i.e. how textbooks were to form part of and support the training of new chemists.

Historians of science have shown how textbooks and practical training in chemistry are compatible in a number of ways. In France, for instance, Thenard's ideal was that all of his students should be able to replicate all his demonstrations and thus he wrote extensive descriptions of these in his textbook (García-Belmar, 2006: 38). The textbook had a central function as it organized different elements (e.g. retorts, substances, and people) and prescribed necessary actions for experiments to work. I will elaborate here a bit more on the case of Britain as described by Brian Dolan as some of his analytical points guides my analysis.

Dolan has studied descriptions of experiments in British nineteenth century chemical textbooks (Dolan, 2000). One of Dolan's central conclusions makes his ideas compatible with the infrastructure vocabulary. Dolan concludes that none of the textbooks he studied - if taken in isolation - featured descriptions with the intention of training experimentalists. Rather, textbooks have to be analyzed in their "pedagogical context", i.e. placed in the network of skills, instruments, institutions, etc. which have to be linked in order to work (Dolan, 2000: 159).

One goal of textbooks was to ensure that readers would obtain the correct result by providing concise descriptions. Anyone who have read a recipe knows that ensuring the intended performance of readers is difficult solely via concise instructions (Dolan, 2000: 143, 156). One way of ensuring consistent results and the success of experimental instruction was to link textbooks assuming specific skills with training kits including standardized samples for experiments. Ultimately, Dolan writes, the linking of textbooks and training kits contributed to presenting chemistry and its experimental techniques as a "coherent" and "reliable" endeavour (Dolan, 2000: 143, 148) Put differently, the chemical substances entering a training situation were standardized to be compatible with the goal of the network (training practical skills in chemistry and introducing students to chemical phenomena).

My analysis starts by describing differences in the experimental descriptions in Forchhammer's and Zeise's textbooks in comparison to Scharling's in section (5.1). I argue that the difference follows from the different ways the textbooks were to participate in teaching situations. I then focus on the textbooks by Forchammer and Zeise in sub-sections (5.2.1) and (5.2.2). I conclude, that Zeise tried to inculcate an ideal of strict order through descriptions of the ideal laboratory and was concerned with presenting chemistry as coherent and rule bound. Finally, I turn to Forchhammer who intended his *Ledetraad* a different function in practical training. In other words, there are different possibilities for textbooks in laboratory networks.

5.1 - Describing experiments

I start my analysis of experimental descriptions with Zeise. Immediately below I show how Zeise included rather precise experimental descriptions while Scharling at times even refrained from mentioning how elements may be obtained.

Zeise's 1829 textbook was a "comprehensive exposition" of pure chemistry. Accordingly it featured some long and precise descriptions of how to obtain substances (Zeise, 1829: vii-viii). Zeise's entry on oxygen may serve as an example. The reader is presented with a rather precise description of how to separate oxygen from "Quægsøloxid"[57] aided by a figure placed at the end of the work as a table (Zeise, 1829: 295, table IV) (reproduced in appendix D). The reader is informed of practical information like actions and suggested instruments: "Man bringe noget af [Quægsølvoxidet] i Bugen af en lille Glasretort [...]"[58] (Zeise, 1829: 295). The reader is instructed on how to set up the equipment and practical rules like using a cork for airtight closure. Then follows information on *what* happens during the experiment, *why*, and *what* to observe. For instance, "[...] Naar Bunden af Retorten begynder at gløde, fremkommer [Ilt] [...]"[59] (Zeise, 1829: 295). Finally the reader is informed on how to test the substance produced by the experimental setup, including the byproduct of mercury in the retort, and on how practically to end the experiment (Zeise, 1829: 295-296). In Zeise's 1829 textbook the aspiring chemist is presented with practical rules but also guided in organizing elements of the laboratory network and observing the actual process.

A similar level of detail is found in Zeise's section on platinum and its related metals. Berzelius' method for obtaining pure platinum, palladium, rhodium, iridium and osmium is explained in detail (Zeise, 1829: 856-864). It is explained as a multi-step thought experiment. One step reads: "den i Kongevand uopløselige Masse tænke vi os hensat indtil videre med Mærket J.O.[60]" (Zeise, 1829: 857). After steps obtaining platinum and palladium the mass dubbed J.O. is reintroduced in the experimental narrative as the final compound to be handled (Zeise, 1829: 859, 861, 861).

These precise descriptions had didactic functions to Zeise. He explicitly argued for the use of experimental descriptions when lecturing as the audience was relieved from note taking. Also, time is saved as some things are learned equally well from print (Zeise, 1829: ix-x). Furthermore, learning chemistry competently required "eksperimental og mundtlig Veiledning"[61] (Zeise, 1829: ix). Thus, the descriptions might be intended for supporting the performing of experiments. I return to this point in sub-section (5.2.1a) below.

Scharling's translation of Wöhler is almost an exact opposite to Zeise's descriptions and there is not a single illustration in the translations (Scharling, 1837; 1841). The production of

[57] "mercuric oxide"
[58] "One brings some [mercuric oxide] into the vessel of a small glass retort"
[59] "when the bottom of the retort starts glowing [oxygen] is produced"
[60] "For the time being we imagine the in aqua regia insoluble mass set aside labeled J.O."
[61] "experimental and oral guidance"

oxygen reads: "**Fremstilling.** Ved Glødning af nogle af dens Forbindelser med Metaller (Metalilter); f. Ex. rødt Quiksølvilte, Bruunsten"[62] (Scharling, 1837: 3, bold letters in original). The process described is the same as Zeise's (For *Bruunsteen*, Zeise, 1829: 301-303) but without a good amount of knowledge of how to set up chemical experiments much is implicit in this description. Similarly, the entry on platinum and its related metals is extremely brief. Scharling's inorganic textbook describes all substances in a systematic order going through: occurrence, production, properties, and combinations. He does so for platinum but for the related metals he only states occurrence and properties in brief omitting both production and combinations without an explanation (Scharling, 1837: 174-178).

The general brevity in descriptions stems from the intention of the textbook. Wöhler's preface describes the textbook as a compendium which should be brief. Accordingly detailed descriptions of apparatus and experiments displaying chemical phenomena are omitted. Instead students needed to experience the apparatus, experiments, and the most important chemical substances during lectures as this would encourage the audience's independent thought (Scharling, 1837: iii-iv). So despite similar intentions of accompanying lectures Scharling's translation and Zeise's textbook were intended to be integrated differently in teaching situations.

The level of descriptive detail in Forchhammer's 1842 textbook is somewhere between Zeise's and Scharling's. In the conclusion of section (4) I mentioned that the contents of the 1842 textbook has been chosen by their function in "Naturens store Huusholdning"[63]. Secondarily, Forchhammer adds, the selection is based on our benefit from them (Forchhammer, 1842: iii). In other words, besides more pure chemistry his textbook contains information on applied chemistry. Here I will outline his description of oxygen (for comparison with Zeise and Scharling) and then briefly sketch parts of the entry on sulphuric acid as an example of the applied chemistry. Forchhammer's more technically oriented *Ledetraad* and its explicit step-by-step instruction of experiments are dealt with in section (5.2.2) below.

Forchhammer's 1842 entry on oxygen is more similar to Zeise's than to Scharling's. Due to an advancement in printing technology the figure representing the experimental setup is now

[62] "**Production.** By making some of its [oxygen's] combinations with metals (metallic oxides) red-hot; e.g. red mercuric oxide, pyrolusite"
[63] "The great economy of nature"

printed in the text alongside the description. Forchhammer describes how to obtain oxygen from *Bruunsteen* but Forchhammer's text reads a bit more like a description of the apparatus than on how to perform the experiment. He states that oxygen may be obtained from *Bruunsteen* by glowing it red hot and then introduces the apparatus on the figure (reproduced in appendix D). Forchhammer writes that "Figuren viser Indretningen af Apparatet"[64] and his description explains the elements on the figure, e.g. that element *a* is a retort made of iron, *b* is a barrel connected to *a* etc., and provides some information on what happens during the process though not as elaborate as Zeise's descriptions (Forchhammer, 1842: 2-3).

Sulphuric acid is described at some length. The value of the sulphuric acid production in relation to chemical factories is compared to the importance of steam engines to the mechanical manufactures (Forchhammer, 1842: 70). Initially the principle of fabrication is outlined using a figure with simple explanations of steps (like the case of oxygen) (represented in appendix E). Then follows some theoretical remarks before introducing a rather complex flowchart overview of the reaction processes (see appendix E). In section (4.2.1) I noted how Forchhammer's flowcharts did not necessarily include all the substances present in the reactions but only the ones needed for describing the reaction. Similarly, Forchhammer state that the flowchart representing the fabrication of sulphuric acid analytically displays a two-stage process indistinguishable in reality (Forchhammer, 1842: 72). The description is accompanied by advice on how factories has brought down costs elsewhere and a table used for estimating the percentage of acid produced. This description with its figures and flowcharts exemplifies how the 1842 textbook includes aspects of applied chemistry. It also shows how the same didactic tools are used for describing pure chemistry and the more applied productions, like the use of flowcharts also seen in the *Ledetraad*.

From the descriptions in the prefaces of textbooks and the actual descriptions found in the textbooks it is clear that Scharling's, Zeise's, and Forchhammer's textbooks were written with a wider network of teaching, substances, and physical objects in mind. It is also evident that textbooks may be network elements in different ways. Scharling's translation was intended to accompany lectures but not to describe the actual experiments. By contrast, both Zeise's and Forchhammer's textbooks assume the availability of apparatus and substances in their more thorough descriptions of experiments. Their textbooks seem more like actual guides for

[64] "the figure displays the setup of apparatus"

working inside a laboratory with their illustrations, practical tips, and observational guides. In the next section I focus on how Zeise's and Forchhammer's textbooks could participate in and support the practical training of chemists.

5.2 - Laboratory Training

That textbooks could actually be intended to support or encourage practical chemical training is not self-evident. Textbooks from France and Sweden may serve as cursory examples: Bensaude-Vincent has remarked how most French textbooks in the first half of the nineteenth century did not "encourage experimental practices" (Bensaude-Vincent, 2000: 281, 292). A complete opposite is found in Swedish textbooks which, according to Lundgren, continuously stressed the need for practical training in order to become a better chemist (Lundgren, 2000: 106, 108).

I will argue in the next two sub-sections that both Zeise and Forchhammer stressed the need for practical training and that their textbooks may be interpreted as active elements in a training laboratory's network. Forchhammer's *Ledetraad* through step-by-step instructions for analytical work and Zeise through practical training in combination with textbooks. Zeise wanted textbooks to convey knowledge of practical chemistry which was central to the learning chemist. I start by focusing on Zeise and his considerations of laboratory practice.

5.2.1 - Strict Order

First of all it is worth considering the architecture of the laboratory. During the nineteenth century designing these to ensure effective ventilation and illumination was "a great difficulty" (Jackson, 2011: 57) but, as other historians have described, the design of training facilities also embodied pedagogical or scientific ideals. For instance, W.H. Brock has described how the architecture of a training laboratory in England at once secured identical working facilities for the students but also arranged the tables to allow constant surveillance by a teacher (Brock, 2017: 52). Or, B. Gee has described how plans for training laboratories were made to such detail that it was required to feature a notebook and pen (Gee, 1989: 54). Implying that chemists are to keep notes during experiments. For the present purposes the specificities around Gee's and Brock's studies are less important than the analytical point that pedagogic ideals or approaches may materialize in the physical facilities surrounding us.

Zeise is no exception to this focus on laboratory design. In the published introduction of his 1840s textbook project, the *Anvisning*, and in lectures held in the early 1840s he presented the ideal laboratory. The lectures and the *Anvisning* have overlaps in content which show that Zeise had introduced his audiences to the ideas for years (Regarding overlaps, compare (Zeise, 1844: 6-8) and (Zeise, 1841-42a: 7-10)). The laboratory described was not in existence and thus the descriptions are idealizations. Nonetheless they are important because they were lectured and published by Zeise as ideals of chemistry.

Zeise discerns two types of laboratory in the description: one for teaching and one which is not for teaching. Both these may again be divided into those meant for "Tilvirkning" or "Undersøgelser"[65] (Zeise, 1844: 6). He describes the need for a well illuminated and ventilated laboratory space (Zeise: 1844: 7). But more emphasis is put on communicating an economy of time as a norm. This ideal of efficiency has practical consequences for the laboratory layout. Not only must oft needed materials and tools be easily and quickly available, but a "stræng Orden" must be mirrored in the laboratory design. This was to ensure that the strict order could easily "iagttages og paasees"[66] (Zeise, 1844: 8; 1841-42a, 10). In his notes the strict order takes the form of a general requirement for the practice of chemistry. Other than time efficiency, his notes state, strict order is the prerequisite for "Nøiagtighed med Arbeiderne" and a "Grundbetingelse for frugtbar chemisk Virksomhed"[67] (Zeise, 1841-42a, 10, original emphasis). From these quotations it is evident that Zeise tried to develop certain ideals in his audience by communicating the norms as requirements for the chemist and by presenting the ideal work space as molded by the same ideals. The economy of time and the demand of strict order is of course linked to his *eminent chemist* who was able to focus on the relevant phenomena and find the shortest and most certain path to improving the knowledge of chemistry (see section (4.3.2)). In other words, the eminent chemist was required to work under strict order and the economy of time. That Zeise's texts focus on these ideals also indicate that Ørsted's memorial volume is not just celebratory when noting Zeise's demands for accuracy, order, and diligence (see section (2.1.1)).

In the analysis of textbooks and theories I quoted Zeise for describing all proper chemistry as practical. In agreement with this conception of chemistry he did not believe that a fruitful insight in chemistry could be taught through lectures alone. It required participation in the

[65] "Production" and "investigation"
[66] "Strict order" and "[be] observed and surveyed"
[67] "Accuracy in the work" and "Fundamental condition for fruitful chemical work"

"udøvelse" of chemistry as well as long-term "øvelse"[68] (Zeise, 1841-42a: 3; 1844: 5). I now discuss how the textbooks by Zeise and Forchhammer could be active elements of a laboratory network. I start by analyzing Zeise's description of the *Övelseslaboratorium.*

5.2.1a - *Övelseslaboratorium*

In section (3) I described how system builders wanted textbooks to fulfill two functions: textbooks should provide an overview of the knowledge infrastructure and facilitate an entry into the knowledge infrastructure. Both these functions are in some sense oriented towards the reader's benefits. However, instruction might yield benefits for others than the students. In his study of Thenard's teaching at the French *École Polytechnique* García-Belmar (2006) have observed "a dual purpose" of the practical instruction. On the one hand, experiments performed trained students in experimental practice. On the other, their experiments supplied the laboratory with skilled personnel (García-Belmar, 2006: 31). A similar multi-purpose of practical instruction may be seen from Zeise's description of the *Övelseslaboratorium*.

Generally, the *Övelseslaboratorium* was intended to allow for certain people to obtain skills in any type of chemical work and specialize in any part of chemistry. It was not for complete beginners but had knowledge of "Chemiens Grundsætninger"[69] as a prerequisite (Zeise, 1822: 57, 59, 61). Part of the training focused on the production of chemical substances, in so far as possible, by the students under the guidance of teachers (Zeise, 1822: 57). Zeise describes a multi-purpose of this teacher guided training. First of all, students of course acquired practical experience with experimental chemical work. But, Zeise adds, the training also resulted in a collection of substances needed for chemical operations and a group of "övede Laboranter"[70] for any chemical operation (Zeise, 1822: 57-58). Practical instruction thus benefitted the *Övelseslaboratorium* materially and in terms of available skills.

That it was students who were engaged with the production of substances was important to Zeise and his pedagogy of chemistry. Zeise explicitly describes this practical training as an advantage over Stromeyer's training laboratory in Göttingen, which Zeise knew from his *Wanderjahre* (see section (2.1.1)). In Göttingen, Zeise wrote, students were only allowed to experiment on premade substances. Consequently students in Göttingen were inexperienced with the production of substances (Zeise, 1822: 58). But Zeise wanted chemists to learn this.

[68] "practice" and "training"
[69] "Foundation of chemistry"
[70] "Trained laboratory technicians"

Besides the benefits for the laboratory I interpret Zeise's emphasis of training in the productive chemistry as a didactic choice. This I base on Zeise's understanding of productive chemistry as more rule-bound. This understanding is evident from his recollections of his *Wanderjahre*, mentioned in the biographical section, where analytical chemistry was described as difficult to teach in any other way than learning by doing. Likewise, his notes for a lecture on chemical instruments and operations state that the lecture focuses on the productive side of chemistry as it "langt lettere bibringes ved regler"[71] (Zeise, 1841-42a: 5, 7). Zeise therefore introduced students to a more rule bound chemistry from the outset of their training.

The question remains how textbooks were supposed to participate in purpose of the laboratory network. In the introduction for the *Anvisning* Zeise describes how textbooks might assist aspiring chemists. He was convinced that the otherwise long-term practice time could be shortened by studying the principles of chemistry and experimental practice in textbooks. These textbook studies were to be paralleled by a careful selection of well prepared and well performed experiments (Zeise, 1844: 6). Thus, the more elaborate descriptions of various experimental setups - and guides as how to observe various chemical phenomena described in section (5.1) - might have been intended for providing the student with the principles of chemistry in order to shorten the time needed to obtain proficiency in chemistry. Likewise with the principles of experimental practice.

Zeise's thoughts on practical training and textbooks can be interpreted as if textbooks were entry points to and organizers of the laboratory network. Textbooks should support and shorten the process of knowledge acquisition by introducing students to the theoretical insights of chemistry *as well as* the practical tips. The practical tips include advice on types of glassware necessary for a given experiment and how to link the experimental elements. Zeise also seems concerned with ensuring that students encountered coherent chemical phenomena and successful experiments. This is seen from the idea of selecting experiments accompanying the textbook studies as stated in the *Anvisning.* Also, it is seen in the supervision of teachers in the *Övelseslaboratorium*.

[71] "[is] by far easier to convey by rules"

5.2.1b - *Organic analysis*

Though not an actual textbook I would like to mention the undated manuscript *Nærmere Anviisning i analytiske Undersøgelse over et Udvalg af organiske Stoffer* published by H.T. Nielsen in 1999. There is no guarantee that what teachers wrote in their textbooks was also practiced in their lectures or let alone in the laboratory instruction. Thus, the manuscript on laboratory instruction is interesting as it provides a glimpse into Zeise's practical teaching and how texts aided this.

In relation to Zeise's pedagogic approach the instructional text embodies two of the points outlined above. The first being the careful selection of experiments, and the second the difficulties of providing rules in analytical chemistry.

Regarding the first, the instructional text is a selection of specific substances and some related exercises introduced to the students. For instance, after listing some substances and how they react with other substances Zeise posed the first exercise. It is an analysis of a solution "med Hensyn til Oxalsyre, Viinsyre, Citronsyre, [og] Æblesyre"[72]. It is based on substances recently introduced in the text and will introduce students to the work of analyzing an unknown solution (Nielsen, 1999: 26-31). The substances also seem to be carefully chosen as oxalic acid served as an important indicator in the analytical work of chemists and the others were among the more common acids found in fruits (On the widespread occurrence of the acids, Zeise: 1847: 133; regarding oxalic acid's analytical importance, Zeise 1847: 109; Forchhammer 1830-31b: 8). Didactically the instructional text proceeds in a similar way in its entire first section: introducing substances and then performing experimental analyses on substances just introduced (Nielsen, 1999: 31-50). The structure explicitly tests and applies the substances introduced in practice. This may seem obvious to a present day reader accustomed to "end-of-chapter" problems in textbooks. However, this didactic structure is not found in any of the other texts studied here. In other words, this text represents a unique didactic strategy of the texts studied for my thesis.

The second point, providing rules, is explicated in the second section of the instructional text with general remarks on analysis. At the general level chemical analysis is described as starting with some sort of "Formodning"[73] on the constitution of the analytical object and this

[72] "with respect to oxalic acid, tartaric acid, citric acid, [and] malic acid"
[73] "presumption"

determines how the analysis begins (Nielsen, 1999: 51). If one does not have a presumption Zeise notes some things to observe, e.g. smell, taste, and colour, but if this does not help he provides a general procedure of 7 steps. Zeise writes that "[...] almindeligviis [er det] raadeligt, at indlede [analysen] med *omtrent* følgende Fremgangsmaade"[74] (Nielsen, 1999: 51, original emphasis). After the first 6 steps Zeise again emphasizes that the procedure cannot be obeyed blindly because results during the preceding steps may render other operations superfluous (Nielsen, 1999: 52). Despite this rather cautionary introduction of the analytical procedure the manuscript represents an attempt made by Zeise for standardizing laboratory procedures. However, his emphasis on the contingent nature of the procedure's order also indicate his conviction that analytical procedures were difficult to standardize.

To conclude Zeise's considerations of textbooks and laboratories it can be said that textbooks were to assist the laboratory network. Textbooks could present readers with explanations of experimental setups, practical tips for their functioning, guides for observation, and the chemical principles behind. Chemistry was practical and thus required practical training which could be time consuming. This could be shortened by the aid of textbooks and by selecting specific experiments. The instructional text on organic analysis may exemplify this latter point of selection. Also, it represents a didactic novelty in its interactive sequence of information on substances and exercises on the same substances.

I now proceed to Forchhammer and specifically the third volume of his *Ledetraad* on analytical chemistry. I will argue that Forchhammer's *Ledetraad* would be able to participate more actively *in* a laboratory setting in comparison with Zeise's 1829 textbook because Forchhammer wrote rather explicit practical instructions in the *Ledetraad*.

5.2.2 - Step by step

Whereas Zeise apparently tried to ensure coherency and success in the practical training of chemists by combining teacher instructions, textbooks, and training the rule-bound production of substances, Forchhammer actually wrote a textbook on chemical analysis. In the following I analyze how Forchhammer's *Ledetraad* includes a detailed step-by-step guides for chemical analysis. The point of interest is how the *Ledetraad* was written as to standardize operations performed in a laboratory network.

[74] "Generally it is advisable to start [the analysis] with *approximately* the following procedure"

The *Ledetraad*, like Zeise's *Anvisning*, explicitly argues by communicating norms and requirements for the chemist. Chemical analysts had to work "hurtigt og med Nøiagtighed"[75]. Also, they are advised to follow Forchhammer's step-wise instructions for analysis as the alternative is to waste "Tid og Umage, uden at faa nogen Sikkerhed i Resultatet"[76] (Forchhammer, 1831b: 35). That is, chemists and chemistry are required to be accurate, efficient, and methodical to ensure confident results.

Continuing to his step-by-step-guide, Forchhammer notes how solutions with few or possibly singular, pure substances present simple situations. Here working with "tilstrækkelig sikkerhed"[77] will result in an identification of the substance(s) in question. However, such conditions are not met with unknown substances, and under such conditions it is "særdeles vigtigt"[78] to follow a specific method (Forchhammer, 1831b: 35). He then introduces his step-by-step methods for analysis which is presented without the amount of cautions made by Zeise.

Forchhammer presents the reader with a general plan of analyzing substances qualitatively. With solids one is to start with a blowpipe analysis and solutions are studied by the wet way of analysis until singular substances are separated. Then the separated substances are to be tested using the blowpipe (Forchhammer, 1831b: 35). Then follows nine pages of minute step-by-step instructions where the reader is provided with explicit instructions on what to do and things to observe. However, there is little information on *why* things happen or the principle behind the procedure provided. For instance, when discussing solids, the book simply goes through what reagents could be added, how the blowpipe flame is to be used, and lists a series of outcomes depending on the observed reactions (Forchhammer, 1831b: 35-38).

The instructions reference each other, that is, reading one instruction the reader might be asked to 'take substance x and proceed to step c' in a completely different instruction (Forchhammer, 1831b: 39). The brevity of descriptions, e.g. the lack of instructions on blowpipe analysis, indicates how the *Ledetraad* was, of course, embedded in a network where other skills were trained independently from the textbook. B. Dolan has described the

[75] "swiftly and with accuracy"
[76] "time and effort without having any reliability in the results"
[77] "sufficient certainty"
[78] "especially important"

difficulties of teaching and using blowpipes which indicates that these skills must have been either prerequisite or trained alongside the *Ledetraad* (Dolan, 2003: 120)

Quantitative analysis is described as *the* important part of chemistry in which one must have *Erfaring* (Forchhammer, 1831b: 45). Forchhammer initially goes through some short definitions of operations like weighing and precipitation. To these he adds some practical tips, e.g. that precipitation is much easier when the solution is heated (Forchhammer, 1831b: 45-47). The remainder of the quantitative instructions consist of step-by-step "Schemata", i.e. actual flowcharts, accompanied by rules and tips placed as comments on adjacent pages (Forchhammer, 1831b: 47-70). The provided flowcharts show the rather applied focus of the *Ledetraad* as they include analytical flowcharts for silver used for coins, metal for canons, different types of iron, or gunpowder among others (Forchhammer, 1831b: 50-53, 56-59, 64-65). The guide for analyzing gunpowder is reproduced as appendix F. It is a flowchart comprised by three steps (A, B, and C) accompanied by tips on duration of heating and what to be cautious about as to avoid wasting resources (Forchhammer, 1831b: 64-65).

The instructions for chemical analysis presented in Forchhammer's *Ledetraad* represents another way textbooks could participate in the network of a training laboratory. Forchhammer's textbook seems intent on being brought *into* the laboratory given its recipe-like instructions with regards to experimental procedures. However, describing its actual use is beyond the reach of my sources. First of all, because the *Ledetraad* is unlikely to have unaided by other instructions or prerequisite skills. For instance, Forchhammer's instructions on the analyses of solids require use of the blowpipe and making qualitative estimates of the colour of the blowpipe flame (Forchhammer, 1831b: 36). Secondly, Forchhammer was (probably) not responsible for the actual practical instructions at the Military Academy where the Danish officer J.C. Hoffmann (1799-1874) also taught chemistry and physics, and was in charge of the academy's chemical laboratory (Kragh, 2005: 286; Scharling, 1857: 79).

5.3 - Conclusion: Textbooks and Laboratories

The analysis provided above shows rather different ways of delegating textbooks a role in teaching and a laboratory network. In general I have focused on Zeise and Forchhammer as Scharling's translation was written as a compendium assisting oral lectures. Accordingly it did not include any experimental descriptions. Zeise and Forchhammer, by contrast, included more elaborate descriptions of chemical phenomena, production, and experiments.

In the case of Zeise proficiency in chemistry could not be obtained without practical experience. This could be time consuming and his textbooks in combination with the instructional manuscript may have been intended for actively facilitating or supporting this acquisition of experience. I argued that Zeize's more elaborate descriptions in the 1829 textbook complemented his didactic plan of paralleling selected chemical experiments with the study of experimental and chemical principles. For instance, the precise description including practical tips in his 1829 textbook might be understood as familiarizing the student with some of the practical rules and experimental principles of the laboratory network.

In the *Övelseslaboratorium* Zeise emphasized how students were to produce substances themselves under the guidance of teachers. Possibly, this choice was also influenced by his conviction that this was a more rule-bound chemical procedure. Zeise emphasized order and the economy of time as norms for chemical practice. The order was a prerequisite for chemistry but also one which should be mirrored in the setup of an ideal laboratory ensuring the control and surveillance of teachers.

The fewer norms communicated by Forchhammer resonate with Zeise's norms. Chemists are required to work efficiently and accurately. In order to satisfy these norms Forchhammer proposes an analytical procedure in his *Ledetraad*. The *Ledetraad* shows another way of implementing textbooks in the laboratory network in comparison to Zeise's. Forchhammer's step-wise instructions are presented with less reservations regarding their functionality than Zeise's instructional text. By featuring a step-by-step instruction for the procedure of analytical chemistry the *Ledetraad* seems like a companion in a laboratory or at least so when practicing the skills of analytical chemistry, e.g. blowpipe analysis and evaluating the chemical phenomena.

This concludes my sections of empirical analyses. I have analyzed a selection of Danish chemical textbooks written by Zeise, Scharling, and Forchhammer. Generally my analysis shows a variety in the possible forms, contents, and functions delegated to the textbooks by their authors. However, a more general outline of my findings and a discussion of my theoretical approach to textbooks will be provided in the following section (6).

6 - Discussion

In the following I would like to discuss my theoretical argument of analyzing textbooks as active elements in knowledge infrastructures. However, before turning to this discussion I will provide an overview of some general findings in the preceding three empirical sections. I outline how my results provide additional nuance to the well established historiography of nineteenth century chemistry (primarily in comparison to work by A.S. Jacobsen and H. Kragh). I divide my general findings into two:

a) didactic strategies (section (6.1a))
b) chemistry as a discipline (section (6.1b)

6.1 - General findings

Jacobsen has argued that Ørsted attempted to establish an infrastructure of dynamical chemical philosophy in Copenhagen through textbooks and teaching, and in the introduction I have noted how Ørsted is described as *the* central scientist in Denmark in the period 1800-1850 (Jacobsen, 2006: 745). Instead of focusing on Ørsted, my study of chemistry textbooks has focused on textbooks by other chemists employed at the university and Polytechnic college in Copenhagen. In the infrastructural vocabulary the chemists can be dubbed *system builders*, i.e. actors concerned with establishing and organizing elements in an infrastructure. In addition to the students, teachers, and institutions my empirical analyses show how the textbook production contributed to the organization and construction of a chemical infrastructure comprised by ideals, theories, and laboratory instructions communicated via textbooks.

However, in the existing historiography the textbooks have not been a central concern. To provide a few examples the old history of Danish chemistry by Veibel merely calls Scharling's translation of Wöhler's *Grundriss* a much needed "modern" textbook in chemistry (Veibel, 1939: 189). Sylvest's thesis on Zeise focused on his general biography and a discussion of parts of his chemical research. Thus, Zeise's textbooks are only mentioned in passing (Sylvest, 1972: 16). Likewise, in the second volume of *Dansk Naturvidenskabs Historie*, mainly by Kragh, both Zeise's and Forchhamer's textbooks are only mentioned briefly. Regarding Zeise he describes Zeise's precautions towards atomism in the 1829 textbook and the existence of the *Haandbog* from 1847. The only textbook by Forchhammer mentioned is the 1842 textbook. It is described as in widespread use, descriptive, experimental, and possibly the first defense of Prout's hypothesis in Denmark (Kragh, 2005:

321, 323-324). Kragh's brevity regarding these textbooks of course have to be considered in light of the limitations of space in a work describing Danish science from 1730-1850 in one volume. I now turn to the matter didactic strategies employed in the textbooks.

6.1a - Didactics

Textbooks as the entry points of infrastructures naturally implies either explicit or implicit didactical considerations. My study of textbooks shows that the chemists, as system builders, were concerned with providing the best possible structure facilitating the teaching of chemistry. This information adds to the knowledge of didactics in chemistry already provided by Jacobsen in the case of Ørsted. For instance, I have shown how textbooks are compatible with educational networks in different ways. These differences followed from the different uses of textbooks in teaching situations. Scharling wanted students to pay close attention to the details of experimental demonstrations and thus omitted detailed descriptions of apparatus and experiments. By contrast, Zeise used his 1829 textbook to provide the audience with elaborate descriptions in order to save time during lectures.

When studying textbooks written purposely as textbooks didactical concerns of course matter. Thus, such textbooks cannot be read merely as a scientific work or a work containing scientific information. It should also be considered how the information is presented and why it is presented as it is. Generally there are two points I would like to emphasize concerning didactics. Firstly, the simple-to-complex ideal, or known-to-unknown, and secondly the standardization of laboratory work.

Forchhamer and Zeise both described how their textbooks were written to ensure a progression in the substances discussed. In other words, their chosen sequences are far from arbitrary. Zeise required his textbook to proceed in a manner where the preceding paved the way for subsequent substances. Judging from his 1829 textbook this took the form of simple to complex as he introduced a number of elements before adding a section on atmospheric air. Forchhammer's 1842 textbook wanted to group elements to illuminate each other in the best way possible. His chosen sequence indicates that the ideal was from known to unknown or simple to complex as he introduced the familiar substance of water as soon as possible in the textbook.

Besides structuring the chemical knowledge, textbooks and instructional texts were also employed to assist and standardize the laboratory instruction. The most explicit examples were Forchhammer's *Ledetraad,* with its step-by-step instructions on analytical chemistry, and Zeise's instructional text on organic analysis. Other than these explicit attempts at prescribing specific actions to their audiences the textbooks by Zeise and Forchhammer included descriptions of experimental setups. These descriptions included practical tips whereby they assisted the organization of the laboratory network.

Textbooks were not the only elements assisting a standardization of the training laboratory. Zeise chose to let students procure substances under the surveillance of a teacher whereas students in Stromeyer's Göttingen had been presented with ready-made substances.

The control of laboratory networks and these more material functions of textbooks are not something I will elaborate on in general as I have not studied these in depth. In fact, it is only recently that the history of science has turned to the more material cultures of practical instruction like in the book *Learning by Doing* (2011) co-edited by P. Heering and R. Wittje (regarding the recent turn of focus, García-Belmar & Bertomeu-Sánchez, 2015: 599). However, these material functions of textbooks *do* deserve more attention due to the glimpses they provide into the practical instruction which was a prerequisite for learning chemistry in the nineteenth century and still is today.

6.1b - Chemistry as a discipline

In section (1.3.1) I described Nye's definition of a disciplinary identity as a network comprised of different elements. In the following I want to focus on norms, theory, and vocabulary as they are organized and presented in the textbooks studied for this thesis. I start with norms as Nye considers these the most important and the foundation for negotiating the other elements of disciplinary identities (Nye, 1993: 29).

Norms

Textbooks communicate and stipulate norms of proper practice within a knowledge infrastructure like chemistry. The most explicit remarks on norms was made by Zeise in both his textbooks and his lectures. These were the norms of his eminent chemist and the requirements of accuracy, order, and diligence as described in Ørsted's memorial volume on Zeise.

The eminent chemist was the almost celebratory description of the talents and skills required by the courageous chemical researcher. Chemists were described as working in the laboratory under the ideals of accuracy and certainty. They were meticulous, accurate, and efficient. The question of efficiency is what I dubbed Zeise's economy of time, i.e. his ideal which demanded chemists to practice their science in a strictly ordered manner: order was the prerequisite for accurate and certain results.

Forchhammer also provided requirements to the chemist, though to a lesser extent than Zeise. Forchhammer's instructions for analytical chemistry prescribed accuracy and efficiency as norms when performing laboratory work. In order to meet these ideals Forchhamer's *Ledetraad* provided readers with a specific method, the step-wise instructions, for analytical chemistry. Forchhammer introduced this procedure implying its ability to save time and ensure certainty in the results. Differently put, accuracy in the results and an economy of time may also be described in Forchhammer's norms of the knowledge infrastructure.

Scharling was less explicit in this regard. However, his translation and the changes he introduced can be taken as indications of what I have described as the central junction of the chemical infrastructure: empirical observations. Empirical observations are presented by the Danish textbooks as *the* centre of chemistry. Scharling added a small section to his 1837 translation of Wöhler. It focused more on definite proportions and atomism as derived from empirical results, the *Erfaring*, than Wöhler's original had.

The centrality of empirical observations is a more general point regarding all the textbooks. Starting from empirical observations textbooks derived concepts of definite proportions and atomism. By extension they often introduced Berzelian formulae but mainly as a functional tool for describing empirical observations. Similarly, the general norms communicated never included an ability to provide theoretical conjectures. By contrast, Zeise described it as a general rule in *Naturlæren* that all ideas must comply with the presently available experience. Though not explicated, a belief is conveyed that simple, empirical facts of nature could present themselves. For instance, both Zeise and Forchhammer describe the chemist as approaching nature without any preconceptions. Furthermore, that these empirical facts should guide our theory.

Theory and atomism

To a certain extent my analyses show that the heading "Chemistry without atoms" used by Kragh et al. (2008) to describe Ørsted's anti-atomism and Zeise's encounter with Parisian chemistry could be extended to most of the textbooks analyzed in this thesis (Kragh et al., 2008: 191-196). None of the textbooks embraced atomism or placed it as the central junction of the chemical infrastructure. Atomism, or other theoretical definitions, were generally confined to specific sections and the bulk of the textbooks were descriptive sections listing a wealth of information. The majority of the textbooks presented atoms in a hypothetical manner deriving it from empirical observations. In the descriptive sections on substances the concept of atoms rarely played any role and more often textbooks were written in an alternative terminology, e.g. *Grunddele*. It should be noted, however, that despite these doubts on the ontological question of atoms a common-sense atomism is present in the majority of the works. For instance, Forchhammer described it as an empirical fact beyond any theoretical speculation that 12,48 hydrogen combines with 100 oxygen (Forchhammer, 1842: 180). In other words, the definite proportions were indisputable but whether one was to assume the existence of miniscule, indivisible parts was another matter.

Vocabulary

In terms of a standardized vocabulary all the textbooks, apart from Zeise's 1829 textbook, introduced or used Berzelian formulae (though none of them credited Berzelius). Thus, I have described this vocabulary as an obligatory passage point for new chemists, i.e. this vocabulary was simply considered a general requirement to learn chemistry. The textbooks introduced the symbolism by arguing for their convenience and without discussing the theoretical or ontological questions of the vocabulary. However, as described in the historical overview, the formulae probably gained widespread use due to their inherent ontological vagueness. This allowed chemists to attribute different assumptions to the same symbolic representations. Scharling's translation of Wöhler is an apt example of this possibility of using Berzelian formulae with different ontological commitments. The German original had described chemical reactions in terms of atoms combining, but Scharling chose to erase all the instances of atoms and substitute them with *Værdital*. Lundgren has actually described how a Swedish translator of Wöhler made a similar substitution of atoms with a more neutral concept (Lundgren, 2000: 98). In other words, atomism and Berzelian formulae were not considered inseparable.

I now turn to a possible critique of my thesis' general approach and focus which may be formulated based on J. Secord's classic article *Knowledge in Transit* (2004) (for its classic status, see Alfonso-Goldfarb et al., 2015: 306). I will show that his critique is not necessarily difficult to satisfy but conclude that my focus has been different from what his ideals concern.

Following this discussion of Secord I proceed to my discussion of the infrastructural approach's merits.

6.2 - Knowledge in Transit

Secord's article is a broad critique of a variety of positions, and here I will focus on some critiques relevant for my thesis and its basic demarcations. Generally Secord suggests focusing on knowledge as communication in order to resolve the historiographical issues he addresses. One central critique he raises regards the use of "unconceptualized geographical and disciplinary boundaries", e.g. the specialization in eighteenth-century French philosophy without knowing "enough" about what occurs beyond these spatial, temporal, or disciplinary limits (Secord, 2004: 656).

Secord criticised a tendency "to see the localizing of a piece of scientific work as a worthwhile end in itself". He warned that the prerequisite for studying knowledge, i.e. contextualizing it, has been mistaken "for actual history" (Secord, 2004: 659). In other words, that the situating of knowledge in a relevant context has been the conclusion rather than the method of historical analysis. Thus, the conclusion remained the same: knowledge is local and variable. In addition, Secord argued, historians risked focusing on practitioners belonging to an esoteric group whose "wider importance is assumed rather than demonstrated" (Secord, 2004: 659).

Secord's critique is easily applied to my thesis. Have I not simply chosen a geographical boundary which we recognize today as Denmark? Chosen a discipline which we recognize as chemistry? Or, chosen three less influential chemists than the main node, namely Ørsted? Before answering the critique it may be useful to outline what Secord suggests as a viable way of studying knowledge in transit.

Secord generally argues for transcending the focus on national states. Even if this is not done, he provides some suggestions for the study of knowledge in transit. The key is considering knowledge as communication. Thus, every time we study *what* is being said we should consider *how*, *where*, *when*, and *for whom* (Secord, 2004: 663-664). The problem is not understanding how knowledge "transcends the local circumstances" but seeing how each local situation has its own "connections with and possibilities for interactions with other settings", and then the studies would be of knowledge *in transit* rather than *in context* (Secord, 2004: 664).

My main response is that by insisting on the indicator-factor duality in textbooks, I address that textbooks cannot be studied merely for *what* they are saying. In addition to *what* one has to consider *how* it is being presented and *why*. To provide a brief empirical example from my analyses, one has to consider *how* atomism is being presented and *why* it may be so. The study of textbooks in the indicative tradition would fall for Secord's critique. However, by acknowledging their active functions textbooks can be considered an obvious source for studying knowledge in transit. This has been argued recently by Simon (2016). Textbooks, he claims, are well fit for producing cross-national histories, and they have an "obvious potential" for connecting research in local, transnational, and global contexts (Simon, 2016: 409-410).

In the following I would like to consider some points from my analysis regarding Secord's suggested focus on potential, and actual, connections or interactions. Though focusing specifically on textbooks written for audiences in Copenhagen, I have actually included observations where the textbooks indicate interactions with chemical knowledge in other parts of Europe. The following section (6.2.1) briefly sketches two examples.

6.2.1 - European interactions

In the second volume of the *Dansk Naturvidenskabs Historie* Kragh describes the almost non-existing contact between Danish and Swedish scientists. This can be considered odd due to our geographical proximity and linguistic similarity. The Danish scientists were oriented towards Germany rather than Sweden. To the extent they were updated on Swedish science it was often mediated through Germany or France (Kragh, 2005: 446-448). This same relation is indicated in the textbooks studied here. All the works used Berzelian symbolism, and most textbooks mention Berzelius by name as a chemist whose results are used and trusted. This could indicate an orientation towards Swedish chemistry. However, the information on Swedish chemistry was mediated via Germany: Scharling translates Wöhler's work based on Berzelius, and Zeise's reference to Berzelius in the opening of his 1829 textbook is to the *Lehrbuch*, i.e. Wöhler's German translation (Zeise, 1829: xv).

Not all the textbooks imply interactions and connections with German chemistry. I mentioned in the biographical section that Forchhammer encountered W. Prout during his *Wanderjahre.* Kragh et al. seem only mention Forchhammer's 1842 textbook to detect the first defense in Danish of "the so-called Proutian hypothesis" (Kragh et al., 2008: 216). In short, Prout's hypothesis stated that "all atomic weights could be expressed as multiples of the weight of hydrogen" as Prout assumed all elemental atoms to consist of a "primordial substance" in form of hydrogen (Kragh et al., 2008: 216).

Now, Forchhammer may of course have been informed of this hypothesis in other ways than his travels to England. But I want to address another aspect of Forchhammer's considerations over hydrogen as unity in calculations. My analysis of Forchhammer's changing attitude towards this question shows that he did indeed argue that all weights could be calculated as multiples of hydrogen's. However, this does not necessarily entail arguing for hydrogen as an primordial substance. Given his emphasis of empirical observations in determining theory it seems less evident that his textbooks argues in favour of Prout's hypothesis, though substantiating this claim would require studies beyond his textbooks. Nonetheless, this case indicates how Forchhammer formed a connection with English chemistry though not simply echoing Prout's hypothesis but only taking certain parts of it.

The two examples provided indicate how textbooks are also influenced by the interactions between geographically different knowledge infrastructures. It is hardly enough to satisfy Secord's demands. This was, however, not my initial point of interest. I was interested in the form, content, and function of textbooks in infrastructures in addition to discussing and analyzing ways to conceive of textbooks as active-indicative sources. Still, the example of Forchhammer's hydrogen discussion suggests that textbooks could be studied as active in the appropriation of theories.

The following section (6.3) will be less concerned with my general, empirical findings regarding nineteenth century chemistry and textbooks. In the following I will offer a discussion of textbooks and their relation to the theoretical approach of knowledge infrastructures.

6.3 - Infrastructures and textbook agency

I have applied Koselleck's indicator-factor distinction to textbooks in order to distinguish more clearly this duality of textbooks. The indicator aspect of textbooks is readily seen from the historiographical history where textbooks were conceived as repositories of accepted knowledge. This conception enabled historians to use them as a checklist of what was known at a given point in time. However, this tradition has been challenged by scholars within STEP or the arguments made by Grafton (2008), Kaiser (2013), or Simon (2013). In the following I discuss the arguments regarding textbook agency and consider how the terminology imported from the perspective of knowledge infrastructures contributes to this.

Generally, I have suggested expanding the list of possible participants in networks beyond the social - which has been the usual network conception. I have suggested using Edwards' infrastructural approach to expand the networks to include not only humans but also norms, laboratories, and objects like textbooks. In doing so, textbooks can be seen as actively contributing to the standardization of vocabulary, theory, norms, and actions to the extent infrastructures limit and enable certain actions.

Providing a rather concrete example, I have discussed the use of textbooks and texts for standardizing actions performed in the laboratory (given that readers followed the instructions as intended). Forchhammer, for instance, wrote minute instructions on what to do in the laboratory in order to assure accurate results. Zeise wanted textbooks to prepare the student for the immersion into the laboratory network via principles and rules. In his instructional text Zeise stipulated analytical challenges on the basis of recently introduced substances requiring the readers to perform specific tasks in the laboratory. In this sense, textbooks may actively participate in the material infrastructure surrounding the chemist in training.

Textbooks may also actively contribute to the fashioning of a self-image or an identity of the academic chemist. One way this happens is through norm communication. The communication of norms is not merely indicatively telling us what the norms of chemists *were* but are likewise assertions of what the norms of chemists *should be*, exemplified in Zeise's eminent chemist. Textbooks can contribute to the establishment of a self-image by communicating and constructing shared norms. Included in the self-image is also an understanding of relations to other knowledge infrastructures. Textbooks can actively participate in the assembly or dismantling of pathways, or borders, between disciplines by organizing the gateways between scientific fields like chemistry and physics.

On the basis of these considerations I would argue for viewing textbooks as indicator-factors, i.e. for acknowledging textbooks as active sources in addition to their more passive, indicative functions. I now turn to the pros and cons of the vocabulary I have formulated under inspiration of knowledge infrastructures. Specifically I discuss the concepts of gateways, entry points, inertia, and junctions

6.3.1 - Pros and cons of an Infrastructural terminology

In the context of an infrastructural vocabulary *gateways* have an analytical advantage over links or connections. Gateways intuitively focuses on the circulation or passage of objects, theories, skills, or similar things. Zeise's *Haandbog* on organic chemistry may serve as an example here. Zeise was not only removing or inserting links between physiology and organic chemistry. He was actually prescribing rules for what things were allowed passage between the two knowledge infrastructures. In other words, gateways not only bring attention to the sharing of theories, objects, and skills, but also how actors try to control the flow through such gateways and demarcate infrastructures from one another.

Whereas gateways may primarily describe connections between different infrastructures the notion of *entry points* describe the facilities provided for initiation *into* a specific knowledge infrastructure. This initiation is needed to familiarize uninitiated with the gateways, internal connections, and customs of an infrastructure. The notion of entry point is more metaphorical than the gateway. By proceeding via a given entry point a reader is provided with certain practical tips, theories, and norms required to act within the chemical infrastructure. In other words, depending on how the infrastructure of chemistry is presented new practitioners are actively formed and informed by textbooks.

I mentioned two functions of textbooks, described by Bertomeu-Sánchez et al. (2002), when analyzed as entry points. According to Bertomeu-Sánchez et al., textbooks had to facilitate the learning process of a target audience, and provide an overview of how the knowledge infrastructure conceives the material world. This meant focusing on the didactic tools used by system builders and the way textbooks organized the knowledge infrastructure to provide an overview.

Now, this description of textbooks as entry points focus on how they actively contribute to the initiation of new practitioners. However, textbooks can also actively erect elements in an immaterial infrastructure. Textbooks can, as noted above, contribute to the fashioning of a self-image by presenting ideals, theories, or practices not yet considered standard in the knowledge infrastructure. For instance, Bensaude-Vincent has argued that Lavoisier's nomenclature reform had major consequences for the self-image of chemists (Bensaude-Vincent, 1996: 496). Lavoisier presented chemistry using a new theory and a new nomenclature without providing a phrase book for translating between the chemical languages. Consequently, the nomenclature reform deprived chemists their historical sense of continuity. Thus, when the new nomenclature became common throughout Europe, it became hard for chemists brought up entirely within the new chemistry to understand their own past. This resulted in a "persistent" belief emerged that chemistry had been "prescientific and obscure knowledge" until the advent of Lavoisier and the chemical revolution (Bensaude-Vincent, 1996: 496).

Knowledge infrastructures are built, maintained, and developed. Textbooks authors can be described as system builders who build and organize knowledge infrastructures using - among other things - textbooks. However, gateways and entry points are insufficient for describing the more general behaviour of knowledge infrastructures. For this purpose Edwards appropriates *inertia* from the LTS-terminology.

Inertia, in one sense, is the rigidity of existing knowledge infrastructures and part of the reason for the incremental change of knowledge infrastructures. If a system builder is trying to continue an existing system inertia provides a strong basis for doing so, whereas manipulating existing infrastructures requires wrestling with their inertia. My empirical work mainly provides examples of the wrestling with existing knowledge infrastructures. However, historian of science K. Olesko has provided arguments in favour of understanding textbooks *actively* contributing to the inertia of existing knowledge infrastructures. Her article was published as part of the special issue in *Science and Education* edited by STEP-participants (Bertomeu-Sánchez et al., 2006). Olesko discusses science pedagogy as an category of historical analysis and thus touches upon textbooks (Olesko, 2006: 873-876). Olesko describes how any acknowledged publication made within a knowledge infrastructure affects or determines the allowed style of thought, e.g. what may be stated and how it is to be expressed (Olesko, 2006: 874). Publications, including textbooks, collectively become a "physical constraint" supporting the way a given knowledge infrastructure conceives the natural world (Olesko, 2006: 874). When Olesko describes textbooks as physical constraints, her terminology is perfectly compatible with Edwards' terminology of infrastructures which mentions inertia and the standardization of actions. Textbooks and inertia can in this case be seen in two ways. Firstly, they reproduce practitioners and thus prolong the existence of theories, vocabularies, and norms. Secondly, and more materially, one could consider the long-term use of textbooks, their continuous publication in different editions, and possibly large print runs making them difficult to replace over night.

To conceive textbooks as wrestling with the inertia of knowledge infrastructures is rather straightforward. Textbooks actively challenging knowledge infrastructures face the only gradual and local change of such complex conglomerates. Looking to my own analyses, imponderables could be an example. I have showed how Zeise questioned their status in chemistry and defined them as a part of physics in his 1829 textbook. However, it seems like more explicit remarks were needed and by 1854 a new translation of Wöhler's *Grundriss* was made which included an explicit rejection of imponderables from the infrastructure of chemistry.

The last infrastructural term I would like to consider is *junction*. Again, the notions of gateways and entry points are not exhaustive in describing the dynamics and geographies of infrastructures. The argument in favour of active textbooks using the notions of entry points and gateways is a bit weaker in my analysis of atomic theory in the textbooks (section (4)). To a large extent this section conceives textbooks as indicators providing information on what stances were taken towards atomism and its vocabulary. However, textbooks can have active functions in terms of junctions as textbooks either support or relocate (central) junctions of the knowledge infrastructure.

That textbooks actually contribute in the establishment a junction may be seen in the textbooks by Zeise, Forchhammer, and Scharling. Ørsted had tried to establish a dynamical as the basis for science, i.e. he had tried to provide theoretical foundations under chemistry based on *Naturphilosphie* (Jacobsen, 2006: 745-746). By contrast, the three chemists studied here explicitly make empirical observations the central junction of chemistry: this was how they derived atomism, argued for theory choices, and for instance Zeise represented empirical experience as a requirement for the chemist in training.

Knowledge infrastructures and the vocabulary of entry points, gateways, junctions, and inertia has strengths and weaknesses - as does any analytical framework. A central reason for applying the infrastructural perspective in this thesis has been the possibility of enlarging the list of network participants actively contributing to the knowledge infrastructure. Depending on the local network, e.g. the laboratory, the infrastructural perspective is good heuristic device for considering the wide range of elements which have to be orchestrated in order to perform in a certain way. I have focused on textbooks and have sketched out ways in which textbooks may *act as* elements in knowledge infrastructures or *manipulate and establish* such elements.

Before turning to my conclusion, I will add one argument for developing and using knowledge infrastructural perspectives. The argument regards the possibility of knowledge infrastructures as a more general framework encompassing different approaches to textbooks and pedagogy.

6.3.2 - Infrastructures as a general framework

Knowledge infrastructures provides a convenient way of thinking about textbooks as active. However, I also see a possibility of considering knowledge infrastructures as a more general framework of textbook and pedagogy studies. The reason being that central concerns from STEP, and other studies of textbooks, can be phrased naturally within the vocabulary of knowledge infrastructures. These central concerns regard knowledge circulation and appropriation.

In terms of knowledge circulation, I have already quoted Bensaude-Vincent - in section (1.3) - for suggesting network analysis as an approach to knowledge circulation (Bensaude-Vincent, 1995: 14). Following her argument, infrastructures allow one to see the gradual diffusion of knowledge, practices, and ideals as a natural consequence of the incremental change and inertia of infrastructures. There is no central node which can enforce changes throughout an infrastructure. It requires, as described by Edwards, negotiation, time, and adjustments to provoke changes across complex infrastructures (Edwards, 2010: 9).

The STEP-programme and other scholars have focused a lot on studying how local actors have appropriated knowledge, i.e. local actors do not simply import knowledge as a commodity. In some instances knowledge is "reinvented" when appropriated (Gavroglu et al., 2008: 163). The core issue is that recipients, whether they are local scholars, teachers, students, or something fourth, never merely receive passively. This perspective follows naturally from knowledge infrastructures. LTS-terminology describes the existence of "technological styles" to describe adaptations of 'the same' system in different local or national contexts (Edwards, 2010: 10). In other words, when entire infrastructures, or simply constitutive elements, travel they do not move as a fixed commodity. In order to adapt to the existing local base variations are introduced by local actors (which Edwards would describe as "developers") (Edwards, 2010: 10). To provide an empirical example the Danish chemists made different adaptations to theories of atomism in order to incorporate such theories in their infrastructural elements, e.g. theories or textbooks. For instance, Ørsted coined the term *"chemical numbers"*[79] to describe the law of multiple proportions in his dynamical chemical philosophy (Jacobsen, 2006: 747, italics in original). Likewise, Scharling substituted most instances of atoms in the translation of Wöhler's textbook.

Already in 1995 Bensaude-Vincent declared that the history of science might benefit from insights made by technology studies (Bensaude-Vincent, 1995: 14). Technology studies, she wrote, have noticed how technological items are rarely used exactly as intended by their inventors, "because it is adapted by the users to their own purposes without regard for the [original intention]" (Bensaude-Vincent, 1995: 14). The historiographical interest in knowledge circulation and appropriation performed by students, teachers, or scholars can be phrased in terms of the inherent tension between system builders, who organize certain infrastructures, and the users who do not comply with all the rules stipulated.

In this sense, I see knowledge infrastructures as a possible overarching framework. Besides providing my thesis with the needed expansion of network participants, and a way of describing textbooks as active, its vocabulary can describe and analyze a lot of historical phenomena of interest.

[79] "chemical numbers"

7. Conclusion: Textbooks and Knowledge Infrastructures

In this master's thesis I have been interested in discussing historiographical questions relating to scientific textbooks. At the general level, I have been interested in arguing in favour of textbooks as sources in the historiography of science and especially in emphasizing their *active* functions. In this conclusion I will summarize the general arguments made in three steps:

I. The indicator-factor distinction
II. Textbooks and identity
III. The vocabulary of knowledge infrastructures

I. The indicator-factor Distinction

In order to describe the history of the textbook historiography I applied Koselleck's distinction between concepts as indicators and factors to textbooks. In the historiography there exists a tradition of *indicative* textbook studies. This tradition sees textbooks as mere approximations of what the body of accepted knowledge is at any given point in time. I traced a genealogy from Kuhn (1962) over Knight (1975) and through Kragh (1987) before noting that historians of physics still practice this type of textbook history. During the 2000s different scholars have reevaluated this understanding of textbooks and a lot of the research referenced in this thesis stems from their reevaluation.

A central conclusion of my thesis is that textbooks are *active* as well as *indicative*. Textbooks are not to be seen as indicators only but as indicator-factors. An important corollary to this conclusion is that textbooks must be read as more than just scientific utterances. In other words, textbooks should not only be analyzed as pure content which tells us something about the state of knowledge. This conclusion follows readily from my empirical analyses where the authors communicate norms, describe theory in specific ways, and make didactic considerations.

Thus, in addition to studying *what* textbooks state we have to consider *who* wrote the textbook, *how* textbooks are (re)presenting the contents and consider *why* authors chose this exposition. Throughout my empirical analyses I have shown how such questions may be answered. For instance, it is not enough to study what is written explicitly of atoms, one also has to take into consideration the structure of the textbook. In addition to this, textbooks are of course shaped by didactical considerations and pedagogic ideals which also have to be taken into consideration instead of merely demonstrating the discussion of a given scientific question in a textbook. Finally, as noted in the discussion of Secord's critique, considering these overall questions in relation to textbooks can also form the basis of interesting studies of knowledge in transit.

In order to conceptualize my focus on textbooks as active, I have suggested considering textbook authors as *system builders* who build or manipulate knowledge infrastructures using textbooks. In the second step of my conclusion I will reiterate one of my empirical examples of textbooks as indicator-factors. The example also shows how textbooks have been used in identity creation.

II. Textbooks and identity

In the introduction I described that I wanted to consider the role of textbooks in the establishing of chemistry as an academic discipline. Therefore, I chose to study a selection of textbooks written in the period immediately following the establishment of chemistry at the university of Copenhagen and the establishment of the Polytechnic College. The textbooks were written by three chemists who taught at both institutions. I have already noted some of my general findings in section (6.1) above. Generally, I have conceived identities as networks comprised by different elements, e.g. shared norms, theories, standardized vocabularies, and common practices. In my empirical sections I have shown how textbooks contribute to *inform* and *form* audiences to comply with the standards of the knowledge infrastructure.

I have also been interested in the active roles of textbooks in establishing identities. I will provide one example here which also showcases how textbooks as indicator-factors not only reflect changes in the sciences but were arguably used to assert new ideals by presenting the chemist and chemistry in a specific manner.

All three authors made remarks which presented chemistry and the chemist in a rather specific manner. Scharling's translation described chemistry as a means for educating the faculty of thought. Approximately at the same time, Forchhammer described chemical knowledge as providing insights into the great economy of nature while also having applied purposes. In other words, both chemists noted chemistry as a pure science. Zeise and his eminent chemist represents the most elaborate attempt at presenting chemistry as a pure science. One studied chemistry first and foremost for the insights it provided and secondarily for its applied purposes.

This is not only indications of an identity in existence. First of all, as described by Kragh, it was part of a broader shift in legitimization strategies of Danish science. Science was no longer defended on the basis of the benefits of its applications but acknowledged as an end in itself. However, it may also be a way of demarcating chemistry from its past as the servant of medicine or other sciences.

It is important to note here that these assertions of chemistry as a pure, independent science are *also* made in textbooks and lectures. Today textbooks are seen as fossilized knowledge and a boring genre of text. However, historically they have been used to form the new generations of scientists and have been used to reshape our understanding of specific disciplines like chemistry.

I now return to the more historiographical considerations of textbooks and specifically to the vocabulary of knowledge infrastructures.

III. The vocabulary of Knowledge Infrastructures

Textbooks were reevaluated during the 2000s. However, despite making a number of historiographical considerations about networks only few STEP-contributions considered broadening the networks beyond the social, human networks.

To develop a framework for studying textbooks as active I have used Edwards' concept of knowledge infrastructures. At a very foundational level, knowledge infrastructures address a materiality and a broadening of elements in the scientific disciplines. Besides the teachers, researchers, and students, knowledge infrastructures consider identities, vocabulary, practices, institutions, and instruments (to name a few elements). In this broadening I have included textbooks using the terminology *entry points, gateways, junctions*, and *inertia*.

Knowledge infrastructures describe how different elements contribute to the initiation of new scientists, the negotiation of identities, and the standardization of practices. I have shown that textbooks actively engage with infrastructures by providing the needed initiation, by contributing to the manipulation of gateways, and by defining shared norms and vocabularies.

My analyses arguably have a bias towards the *immaterial* aspect of infrastructures. This follows from the nature of textbooks as *texts*. It is simply much more convenient to analyze their connections with other texts, theories, norms, or ideals of science and textbook writing. The immaterial sense can be put briefly by reference to Olesko and the concept of inertia.

Textbooks contributes to the consolidation of standardized norms or ways of using theory in a knowledge infrastructure. It contributes to the "physical constraints" of viable modes of thought, descriptions of the world, or norms of scientific practice. If enough publications, including textbooks, describe the same phenomena, identities, or practices they contribute to giving the infrastructures comprised by these more inertia - which in turn makes them more difficult to alter.

However, knowledge infrastructures also provide a way of analyzing textbooks as active elements of *material* networks. Practices and actions have to be standardized in order for infrastructures to work. I have shown how textbooks presented experimental descriptions and described how system builders may have intended for their practical functions *in* laboratories. Textbooks can stipulate actions, or standardize analytical procedures, which of course is no guarantee of success. The material interactions and the user perspective of textbooks are difficult to study. The perspective of knowledge infrastructures suggests one way of focusing more on the role of non-human entities like textbooks in the laboratory. Still, this is a perspective of textbooks which deserves further attention.

In conclusion textbooks are much more than simple echoes from the frontiers of research. They are indicator-factors forming part of and actively interacting with the knowledge infrastructures.

Bibliography

Alfonso-Goldfarb, A.M., Chang, H., Ferraz, M.H.M., Rampling, J.M. & Waisse, S. 2015, "Chemical Knowledge in Transit", *Ambix*, vol. 62, no. 4, pp. 305-311.

Badino, M. & Navarro, J. (eds) 2013a, *Research and pedagogy : a history of quantum physics through its textbooks*, Edition Open Access, Germany.

Badino, M. & Navarro, J. 2013b, "Pedagogy and Research. Notes for a Historical Epistemology of Science Education" in *Research and Pedagogy: A History of Quantum Physics though Its Textbooks*, eds. M. Badino & J. Navarro, Edition Open Access, Germany, pp. 7-26.

Bensaude-Vincent, B. 1995, "A Geographical History of Eighteenth-Century Chemistry" in *Lavoisier in European context : negotiating a new language for chemistry*, eds. B. Bensaude-Vincent & F. Abbri, Science History Publication/USA, Canton, MA, pp. 1-18.

Bensaude-Vincent, B. 1996, "Between History and Memory: Centennial and Bicentennial Images of Lavoisier", *Isis*, vol. 87, no. 3, pp. 481-499.

Bensaude-Vincent, B. 2000, "From Teaching to Writing: Lecture Notes and Textbooks at the French *École Polytechnique*" in *Communicating Chemistry: Textbooks and their Audiences, 1789-1939*, eds. A. Lundgren & B. Bensaude-Vincent, Science History Publications/USA, Canton MA, pp. 273-294.

Bensaude-Vincent, B. 2006, "Textbooks on the Map of Science Studies", *Science & Education*, vol. 15, no. 7, pp. 667-670.

Bensaude-Vincent, B. 2007, "College Chemistry: how a textbook can reveal the values embedded in chemistry", *Endeavour*, vol. 31, no. 4, pp. 140-144.

Bensaude-Vincent, B. & Abbri, F. (eds) 1995, *Lavoisier in European context : negotiating a new language for chemistry*, Science History Publications, Canton. pp.1-43

Bensaude-Vincent, B. & García-Belmar, A. 2015, "Mendeleev's Periodic Classification and Law in French Chemistry Textbooks" in *Early Repsonses to the Periodic System*, eds. M. Kaji, H. Kragh & P. Gábor, Oxford University Press, , pp. 103-120.

Bensaude-Vincent, B. & Stengers, I. 1996, *A history of chemistry*, Harvard University Press, Cambridge, Mass. pp.1-11, 44-160

Bertomeu-Sánchez, J.R. (ed) 2006, *Chemistry, medicine, and crime, Mateu J.B. Orfila (1787-1853) and his times*, Science History Publications/USA, Sagamore Beach, MA. pp.25-51

Bertomeu-Sánchez, J.R., García-Belmar, A. & Bensaude-Vincent, B. 2002, "Looking for an order of things: textbooks and chemical classifications in nineteenth century France", *Ambix*, vol. 49, no. 3, pp. 227-250.

Bertomeu-Sánchez, José R., García-Belmar, A., Lundgren, A. & Patiniotis, M. 2006, "Introduction: Scientific and Technological Textbooks in the European Periphery", in García-Belmar et al. (eds) 2006, pp.657-665

Biagioli, M. & Galison, P. (eds) 2003, *Scientific authorship : credit and intellectual property in science,* Routledge, New York. pp.1-12, 133-164

Biering, C.H. 1838, *Grundrids af Plantechemien,* , Kbh.

Blondel-Mégrelis, M. 2000, "Berzelius' Textbook: In Translation and Multiple Editions, as Seen Through His Correspondence" in *Communicating Chemistry: Textbooks and their Audiences, 1789-1939*, eds. A. Lundgren & B. Bensaude-Vincent, Science History Publications/MA, Canton MA, pp. 233-254.

Bostrup, O. 1996, *Dansk kemi 1770-1807 : den kemiske revolution,* Teknisk Forlag, Kbh. pp.3-18, 125-150, 193-201

Brock, W.H. 2017, *British School Chemistry Laboratories, 1830-1920* Ambix - The Journal of the Society for the History of Alchemy and Chemistry, vol.64, no.1, pp.43-65

Brooke, J.H. 2000, "Introduction: *The Study of Chemical Textbooks*" in *Communicating Chemistry: Textbooks and their Audiences, 1789-1939*, eds. A. Lundgren & B. Bensaude-Vincent, Science History Publications, Canton, MA, pp. 1-18.

Buchwald, J.Z. & Fox, R. (eds) 2013, *The Oxford handbook of the history of physics,* Oxford University Press, Oxford, United Kingdom:. pp.651-678

Callon, M., Lascoumes, P. and Barthe, Y. (2011). *Acting in an uncertain world*. 1. ed.. Cambridge, Mass.: MIT Press

Callon, M., Law, J. & Rip, A. (eds) 1986, *Mapping the dynamics of science and technology : sociology of science in the real world*, Macmillan, Basingstoke. pp. 19-51

Campi, E., De Angelis, S., Goeing, A.-. & Grafton, A. (eds) 2008, *Scholarly Knowledge: Textbooks in early modern Europe*, Librairie Droz S.A., Geneve. pp.11-36

Dolan, B. 2000, "The Language of Experiment in Chemical Textbooks: Some Examples from Early nineteenth-Century Britain" in *Communicating Chemistry: Textbooks and their Audiences, 1789-1939*, eds. A. Lundgren & B. Bensaude-Vincent, Science History Publications/USA, Canton MA, pp. 141-164.

Dolan, B. 2003, "Embodied Skills and Travelling Savants: Experimental Chemistry in Eighteenth-Century Sweden and England" in *Travels of Learning: A Geography of Science in Europe*, eds. A. Simões, A. Carneiro & M.P. Diogo, Kluwer Academic Publishers, Boston, Mass., pp. 115-143.

Edwards, P.N. 2003, "Infrastructure and Modernity: Force, Time, and Social Organization in the History of Sociotechnical Systems" in *Modernity and Technology*, eds. T.J. Misa, P. Brey & A. Feenberg, MIT Press, Cambridge, MA, pp. 185-225.

Edwards, P.N. 2010, *A vast machine : computer models, climate data, and the politics of global warming*, MIT Press, Cambridge, Mass. pp.1-25

Forchhammer, J.G. 1830-31a, *Ledetraad ved Forelæsningerne over Chemie ved den kongelige militaire Høiskole, 1830-31: I Hæfte, Uorganisk Chemie*, , Kbh.

Forchhammer, J.G. 1830-31b, *Ledetraad ved Forelæsningerne over Chemie ved den kongelige militaire Høiskole, 1830-31:2nden Deel (den bogtrykte Part) af I Hæfte. Den Uorganisk Chemie*, , Kbh.

Forchhammer, J.G. 1831a, *Ledetraad ved Forelæsningerne over Chemie ved den kongelige militaire Høiskole, 1831: II Hefte. Den organiske Chemie*, , Kbh.

Forchhammer, J.G. 1831b, *Ledetraad ved Forelæsningerne over Chemie ved den kongelige militaire Høiskole, 1831: III Hefte, Den analytiske Chemie*, , Kbh.

Forchhammer, J.G. 1834-35, *Lærebog i Stoffernes almindelige Chemie : 1-2. H. (1 Vol.)*, , Kbh.

Forchhammer, J.G. 1842, *Lærebog i Stoffernes almindelige Chemie : D. 1. De enkelte Radikalers almindelige Chemie*, C. A. Reitzel, Kbh.

Forchhammer, J.G. 1869, *Almeenfattelige Afhandlinger og Foredrag : Med Forfatterens Biographi og en Fortegnelse over hans litterære Arbejder ved F. Johnstrup*, F. L. Thaarup, Kbh. pp.iii-xl

García-Belmar, A. 2006, "The Didactic Uses of Experimen: Louis-Jacques Thenard's Lectures at the *Collège de France*" in *Chemistry, medicine, and Crime, Mateu J. B. Orfila (1787-1853) and his times*, ed. J.R. Bertomeu-Sánchez, Science History Publications/USA, Sagamore Beach, MA, pp. 25-51.

García-Belmar, A. & Bertomeu-Sánchez, J.R. 2003, "Constructing the Centre from the Periphery: Spanish Travellers to France at the Time of the Chemical Revolution" in *Travels of Learning: A Geography of Science in Europe*, eds. A. Simões, A. Carneiro & M.P. Diogo, Kluwer Academic Publishers, Boston, Mass., pp. 143-188.

García-Belmar, A., Bertomeu-Sánchez, J.R. & Bensaude-Vincent, B. 2005, "The Power of Didactic Writing" in *Pedagogy and the Practice of Science*, ed. D. Kaiser, MIT, Cambridge, Massachussetts, London, England, pp. 219-252.

García-Belmar, A. & Bertomeu-Sánchez, J.R. 2015, "Learning by Writing. Chemistry Student Notebooks and Lecture Demonstrations in Early 19th Century France", *Archives Internationales d'histoire des Sciences*, vol. 65, no. 175, pp. 599-615.

García-Belmar, A., Bertomeu-Sánchez, J.R., Patiniotis, M. & Lundgren, A. (eds) 2006, "Special Issue: Textbooks in the Scientific Periphery", *Science & Education,* vol. 17, no. 7-8, pp. 657-880

Gavroglu, K. & Simões, A. 2000, "One Face or Many? The Role of Textbooks in Building the New Discipline of Quantum Chemistry" in *Communicating Chemistry: Textbooks and their Audiences, 1789-1939*, eds. A. Lundgren & B. Bensaude-Vincent, Science History Publications/USA, Canton, MA, pp. 415-451.

Gavroglu, K., Patiniotis, M., Papanelopoulou, F., Simoes, A., Carneiro, A., Diogo, M.P., Bertomeu Sánchez, J.R., Belmar, A.G. & Nieto-Galan, A. 2008, "Science and Technology in the European Periphery: Some Historiographical Reflections", *History of Science,* vol. 46, no. 2, pp. 153-175.

Gee, B. 1989, "Amusements Chests and Portable Laboratories: Practical Alternatives to the Regular Laboratory" in *The Development of the Laboratory*, ed. F.A.J.L. James, Macmillan Press, Basingstoke, pp. 37-61.

Gmelin, L. 1827, *Handbuch der theoretischen Chemie,* 3rd edn, Franz Varrentrapp, Framkfurt am Main. pp.iii-xii, 1-5. Accessed online through Google Books: https://books.google.dk/books?id=0pxRAAAAMAAJ&pg=PA199&dq=gmelin+handbuch+der+theoretischen+chemie&hl=da&sa=X&ved=0ahUKEwjasYaSl87bAhXpO5oKHXVXBDkQ6AEIJzAA#v=onepage&q&f=false [Last accessed 12-06-2018]

Grafton, A. 2008, "Textbooks and the Disciplines" in *Scholarly Knowledge: Textbooks in early modern Europe*, eds. E. Campi, S. De Angelis, A.-. Goeing & A. Grafton, Librairie Droz S.A., Geneve, pp. 11-36.

Groth, S. 1854, *F. Wöhler's Grundrids af den uorganiske Chemie*, Reitzel, Kbh.

Groth, S. 1855, *F. Wöhler's Grundrids af den organiske Chemie*, Reitzel, Kbh.

Habashi, F. 2009, "Gmelin and his Handbuch", *Bulletin for the history of chemistry,* vol. 34, no. 1, pp. 30-31.

Haupt, B. 1987, *Deutschsprachige Chemielehrbücher (1775-1850),* Deutscher Apotheker Verlag, Stuttgart. pp.v-xiii, 1-10, 226-297

Heering, P., Wittje, R. 2011, *Learning by doing : experiments and instruments in the history of science teaching*, Franz Steiner Verlag, Stuttgart, pp.7-70, 97-113, 281-348

Homburg, E. 1998, "Two factions, one profession: the chemical profession in German society, 1780-1870" in *The Making of the Chemist: The Social History of Chemistry in Europe, 1789-1914*, eds. D. Knight & H. Kragh, Cambridge University Press, Cambridge, pp. 39-77.

Jackson, C.M. 2011, "Chemistry as the defining science: discipline and training in nineteenth-century chemical laboratories", *Endeavour,* vol. 35, no. 2, pp. 55-62.

Jacobsen, A.S. 2000a, *Between naturphilosophie and tradition : Hans Christian Ørsted's dynamical chemistry,* Ph.D. Thesis, University of Aarhus. pp. ix-xv, 1-17, 123-271

Jacobsen, A.S. 2000b, "A.W. Hauch's Role in the Introduction of Antiphlogistic Chemistr into Denmark", *Ambix*, vol. 47 (2), pp.71-95

Jacobsen, A.S. 2005, "Universiteterne i Kiel og Chrstiania", in Kragh (2005) pp.270-277

Jacobsen, A.S. 2006, "Propagating Dynamical Science in the Periphery of German Naturphilosophie: H. C. Ørsted's Textbooks and Didactics", *Science & Education,* vol. 15, no. 7, pp. 739-760.

James, F.A.J.L. 1989, *The development of the laboratory : essays on the place of experiment in industrial civilization,* Macmillan, Basingstoke. pp.1-61

Jensen, K.A., 1983 "Kemi", in Pihl, M. (ed) (1983), *Københavns Universitet 1479-1979*, Vol..12, Gads Forlag, Copenhagen. pp.427-580

Johnstrup, F.L. 1869, "Johan Georg Forchhammers Levnet" in Forchhammer, J. G. 1869, pp.xi-xl

Jordheim, H. 2012, "AGAINST PERIODIZATION: KOSELLECK'S THEORY OF MULTIPLE TEMPORALITIES", *History and Theory,* vol. 51, no. 2, pp. 151-171.

Kaiser, D. (ed) 2005a, *Pedagogy and the practice of science : historical and contemporary perspectives,* MIT Press, Cambridge, Mass.

Kaiser, D. 2005b, "Introduction: Moving Pedagogy from the Periphery to the Center" in *Pedagogy and the Practice of Science*, ed. D. Kaiser, MIT Press, Cambridge, Mass., pp. 1-10.

Kaiser, D. 2013, "Epilogue: Textbooks and the Emergence of a Conceptual Trajectory" in *Research and Pedagogy: A History of Quantum Physics through Its Textbooks,* eds. M. Badino & J. Navarro, Edition Open Access, Germany, pp. 285-289.

Kaji, M., Kragh, H. & Gábor, P. (eds) 2015, *Early responses to the periodic system*, Oxford University Press, New York, NY. pp.1-13, 103-120, 153-213, 283-305

Klein, U. 1999, *Techniques of modelling and paper-tools in classical chemistry*. In Morgan & Morrison (eds) (1999). pp.146-167.

Klein, U. (ed) 2001, *Tools and modes of representation in the laboratory sciences,* Kluwer Academic Publishers, Dordrecht. pp.vii-xv, 1-35

Klein, U. 2003, *Experiments, models, paper tools : cultures of organic chemistry in the nineteenth century,* Stanford University Press, Stanford, Calif.1-118

Klein, U. 2005, "Shifting ontologies, changing classifications: plant materials from 1700 to 1830", *Studies in History and Philosophy of Science,* vol. 36, no. 2, pp. 261-329.

Kjærgaard, P.C. (ed) 2006, *Dansk naturvidenskabs historie : 1850-1930,* Aarhus Universitetsforlag, Århus., pp.119-141

Knight, D. 1975, *Sources for the history of science 1660-1914,* Cornell Univ. Press, Ithaca. pp.127-186

Knight, D. 2009, *The making of modern science : science, technology, medicine and modernity: 1789-1914,* Polity, Cambridge. pp.1-11, 129-150, 264-282

Knight, D.M., & Kragh, H. (eds) 1998, *The making of the chemist : the social history of chemistry in Europe, 1789-1914,* Cambridge University Press, Cambridge. pp.vii-xxi, 3-15, 39-77, 235-264, 329-343.

Koselleck, R. 2007, *Begreber, tid og erfaring : en tekstsamling,* 1. ed, Hans Reitzel, Kbh. pp.27-81

Kragh, H. 1987, *An introduction to the historiography of science,* Cambridge univ. Press, Cambridge.

Kragh, H. 1998a, "Out of the Shadow of Medicine: Themes in the Development of Chemistry in Denmark and Norway" in *The Making of the Chemist: the Social History of Chemistry in Europe, 1789-1914*, eds. D. Knight & H. Kragh, Cambridge University Press, Cambridge UK, pp. 235-264.

Kragh, H. 1998b, "*Afterword*: The European Commonwealth of Chemistry", in *The Making of the Chemist: the Social History of Chemistry in Europe, 1789-1914,* eds. D. Knight & H. Kragh, Cambridge University Press, Cambridge UK, pp.329-343

Kragh, H. 2005, *Natur, nytte og ånd : 1730-1850,* Aarhus Universitetsforlag, Århus. pp.9-111, 147-325, 360-372, 408-486

Kragh, H. 2016, *Julius Thomsen : a life in chemistry and beyond,* Det Kongelige Danske Videnskabernes Selskab, Kbh. pp. 7-50

Kragh, H., Kjærgaard, P.C., Nielsen, H. & Hvidtfelt Nielsen, K. (eds) 2008, *Science in Denmark : a thousand-year history,* Aarhus University Press, Århus. pp.7-23, 129-240, 545-549

Kragh, H. & Styhr Petersen, H.J. 1995, *En nyttig videnskab : episoder fra den tekniske kemis historie i Danmark,* Gyldendal, Copenhagen. pp.7-81

Kuhn, T. 2012, *The Structure of Scientific Revolutions*. 4th ed.. Chicago: The University of Chicago Press

Latour, B. & Woolgar, S. 1986, *Laboratory life : the construction of scientific facts*, 6. pr. edn, Princeton Univ. Press, Princeton, N. J. 11-14, 43-103

Lauritsen, E.N. 2017,, *Lærebøger i skraldespanden: Dino-forskere reagerer på skelsættende studie [Textbooks in the trash can: Dino-researchers reacto to path-breaking study]* [Homepage of Videnskab.dk], [Online]. Available: https://videnskab.dk/naturvidenskab/laereboeger-i-skraldespanden-dino-forskere-reagerer-paa-skelsaettende-studie [Accessed 2018, 6/7].

Law, J. 1986, "Laboratories and Texts" in *Mapping the dynamics of science and technology : sociology of science in the real world*, eds. M. Callon, J. Law & A. Rip, Macmillan, Basingstoke, pp. 35-50.

Lightman, B.V. (ed) 2016, *A companion to the history of science*, John Wiley & Sons, Chichester, UK. pp.400-414

Lockemann, G. & Oesper, R.E. 1953, "Friedrich Stromeyer and the history of chemical laboratory instruction", *Journal of chemical education*, vol. 30, no. 4, pp. 202-204.

Lundbye, J.T. 1929, *Den polytekniske Læreanstalt : 1829-1929*, Gad, Kbh. pp.7-97, 362-379

Lundgren, A. 1995, "The Chemical Revolution from a Distance: Anders Gustaf Ekeberg, the Antiphlogistic Chemistry, and the Swedish Scene" in *Lavoisier in European context : negotiating a new language for chemistry*, eds. B. Bensaude-Vincent & F. Abbri, Science History Publication/USA, Canton, MA, pp. 19-43

Lundgren, A. 2000, "Theory and Practice in Swedish Chemical Textbooks during the Nineteenth Century: Some Thoughts from a Bibliographical Survey" in *Communicating Chemistry: Textbooks and their Audiences, 1789-1939*, eds. A. Lundgren & B. Bensaude-Vincent, Science History Publications/USA, Canton MA, pp. 91-118.

Lundgren, A. & Bensaude-Vincent, B. (eds) 2000, *Communicating chemistry : textbooks and their audiences, 1789-1939*, Science History Publications/USA, Canton, MA.

Meyer, K. (ed) 1920, *H.C. Ørsted: Scientific Papers, 2. volume* (3. vols. total), Høst & Søn, Copenhagen, pp.555-568.

Misa, Thomas J. *Leonardo To The Internet*. 1st ed. Baltimore: Johns Hopkins Univ. Press, 2011. Print.

Misa, T.J., Brey, P. & Feenberg, A. (eds) 2003, *Modernity and technology*, MIT Press, Cambridge, Mass. pp.185-225

Morgan, M.S. & Morrison, M. 1999, *Models as mediators : perspectives on natural and social science*, Cambridge University Press, Cambridge. pp.146-167

Nielsen, A.K. 1998, "Kemien i København - netværk og niveau" in *Videnskabernes København*, eds. T. Söderqvist, J. Faye, H. Kragh & F.A. Rasmussen, Roskilde Universitetsforlag, Gylling, pp. 180-200.

Nielsen, A.K. 2000, *The chemists : Danish chemical communities and networks, 1900-1940*, Vol. I, Ph.D. Thesis, University of Aarhus. pp.1-101

Nielsen, A.K. 2006, "Kemi", in Kjærgaard (ed) 2006, pp.119-141

Nielsen, A.K. 2007, "Fashioning and Demarcation of the Danish Chemical Community in the 19th Century", *Centaurus*, vol. 49, no. 3, pp. 199-226.

Nielsen, A.K. 2008, "DENMARK: Creating a Danish Identity in Chemistry between Pharmacy and Engineering, 1879-1914" in *Creating Network in Chemistry: The Founding and Early Hisotry of Chemical Societies in Europe*, eds. A. Kildebæk Nielsen & S. Štrbáňová,, The Royal Society of Chemistry, Cambridge UK, pp. 75-90.

Nielsen, A.K. & Štrbáňová, S. (eds) 2008, *Creating networks in chemistry : the founding and early history of chemical societies in Europe*, Royal Society of Chemistry, Cambridge, UK. pp.v-xi, 75-90, 328-348

Nielsen, H.T. 1994, "Kemikeren J.G. Forchhammer", *Dansk kemi*, vol. Årg. 75, nr. 12 (1994), pp. 20-24.

Nielsen, H.T. 1999, *Maximilian Bruhns Zeise-bog*, Dansk Selskab for Historisk Kemi, Fredensborg

Nye, M.J. 1993, *From chemical philosophy to theoretical chemistry : dynamics of matter and dynamics of disciplines, 1800-1950,* University of California Press, Berkeley. pp.1-105, 262-313

Nye, M.J. (ed) 2003, *The Cambridge History of Science, Vol. 5: The Modern Physical and Matehematical Sciences*, Cambridge University Press, United States of America. pp.1-21, 174-190, 237-272

Olesko, K.M. 2006, "Science Pedagogy as a Category of Historical Analysis: Past, Present, and Future", *Science & Education*, vol. 15, no. 7, pp. 863-880.

Partington, J.R. 1964, *A history of chemistry Vol.* 4, Macmillan, London. pp.233-264

Petrou, G. 2006, "Translation Studies and the History of Science: The Greek Textbooks of the 18th Century", *Science & Education*, vol. 15, no. 7, pp. 823-840.

Pihl, M. (ed) 1983, *Københavns Universitet 1479-1979* (vol.12), Gads Forlag, Copenhagen. pp.427-580.

Ramberg, P.J. 2000, "The death of vitalism and the birth of organic chemistry: Wohler's urea synthesis and the disciplinary identity of organic chemistry", *Ambix,* vol. 47, no. 3, pp. 170-195.

Riis Larsen, B. 1991, *Naturvidenskab og dannelse : studier i fysik- og kemiundervisningens historie i den højere skole indtil midten af 1800-tallet,* Selskabet for historisk Kemi, Espergærde. pp.222-344

Rocke, A.J. 1984, *Chemical atomism in the nineteenth century, from Dalton to Cannizzaro,* Ohio State University Press, Columbus. pp. xi-xviii, 1-49, 153-215

Rocke, A.J. 2001a, *Nationalizing science : Adolphe Wurtz and the battle for French chemistry,* MIT Press, Cambridge, Mass. pp.73-101

Rocke, A.J. 2001b, "Chemical Atomism and the Evolution of Chemical Theory in the Nineteenth Century" in *Tools and Modes of Representation in the Laboratory Sciences*, ed. U. Klein, Kluwer Academic Publishers, Dodrecht, Netherlands, pp. 1-13.

Scharling, E.A. 1837, *F. Wöhler's Grundrids af Chemien: Uorganisk Chemie,* Reitzel, Kbh.

Scharling, E.A. 1841, *F. Wöhler's Grundrids af Chemien: Organisk Chemie,* Reitzel, Kbh.

Scharling, E.A. 1857, *Bidrag til at oplyse de Forhold : under hvilke Chemien har været dyrket i Danmark,* tr. : J. H. Schultz, Kbh.

Schütt, H.-W. 2003, "Chemical Atomism and Chemical Classification" in *The Cambridge History of Science, Vol.5: The Modern Physical and Mathematical Sciences*, ed. M.J. Nye, Cambridge University Press, United States of America, pp. 238-254.

Secord, J.A. 2004, "Knowledge in Transit", *Isis,* vol. 95, no. 4, pp. 654-672.

Seligardi, R. 2006, "Views of Chemistry and Chemical Theories: A Comparison between two University Textbooks in the Bolognese Context at the Beginning of the 19th Century", *Science & Education*, vol. 15, no. 7, pp. 713-737.

Simões, A., Carneiro, A. & Diogo, M.P. (eds) 2003a, *Travels of learning : a geography of science in Europe*, Kluwer Academic Publishers, Boston, Mass. pp.v-xiv, 1-18, 115-188

Simões, A., Carneiro, A. & Diogo, M.P. 2003b, "Travels of Learning, Introductory Remarks" in *Travels of Learning: A Geography of Science in Europe*, eds. A. Simões, A. Carneiro & M.P. Diogo, Kluwer Academic Publishers, Boston, Mass., pp. 1-18.

Simon, J. 2013, "Physics Textbooks and Textbook Physics in the Nineteenth and Twentieth Centuries" in *The Oxford Handbook of The History of Physics*, eds. J.Z. Buchwald & R. Fox, Oxford University Press, Oxford, UK, pp. 651-678.

Simon, J. 2016, "Textbooks" in *A Companion to the History of Science*, ed. B.V. Lightman, John Wiley and Sons, Chichester, UK, pp. 400-414.

Sjøgren, K. 2018, *Forskere: Lærebøger om Immuforsvaret skal skrives om [Scientists: Textbooks on the immune system will have to be rewritten]* [Homepage of Videnskab.dk], [Online]. Available: https://videnskab.dk/krop-sundhed/forskere-laereboeger-om-immunforsvaret-skal-skrives-om [Accessed 2018, 6/7].

Söderqvist, T., Faye, J., Kragh, H. & Rasmussen, F.A. (eds) 1998, *Videnskabernes København*, Roskilde Universitetsforlag, Frederiksberg. pp.7-25, 180-201

Sylvest, S.B. 1972, *W.C. Zeise*, Master's Thesis, University of Aarhus

Tapdrup, J. 1998, *Textbooks in transition : disciplinary and texonomic developments in examples of late 18th century natural philosophy*, Master's Thesis, University of Aarhus

Udvalg for Bedre Universitetsuddannelser. 2018, *Samlede Anbefalinger*. Uddannelses- og Forskningsministeriet. Online: https://ufm.dk/uddannelse/rad-naevn-og-udvalg/udvalg-om-bedre-universitetsuddannelser/filer/uuu-udvalgets-samlede-anbefalinger.pdf [Last accessed 13-6-2018]

Veibel, S. 1939, *Kemien i Danmark, Vol. I* (3 vols. total published between 1939-1964*)*, Nyt Nordisk Forlag, Arnold Busck, Kbh. pp.141-224

Vicedo, M. 2012, "Introduction: The Secret Lives of Textbooks", *Isis*, vol. 103, no. 1, pp. 83-87.

Warwick, A. 2003, ""A Very Hard Nut to Crack" or Making Sense of Maxwells *Treatise on Electricity and Magnetism* in Mid-Victorian Cambridge" in *Scientific Authorship: Credit and Intellectual Property in Science*, eds. M. Biagioli & P. Galison, Routledge, , pp. 133-164.

Zeise, W.C. 1822, "Om det hos os oprettede offentlige chemiske Övelseslaboratorium", *Tidsskrift for Naturvidenskaberne*, vol. 1, pp. 56-63.

Zeise, W.C. 1829, *Udførlig Fremstilling af Chemiens Hovedlærdomme saavel i theoretisk som practisk Henseende*, Fr. Brummer, Kbh.

Zeise, W. C. (1841-42a), *For Foredraget over de chemiske Instrumenter og Operationer, ved Universitetet, Vintersemestret 1841-42* [En.: *For the lecture on chemical instruments and operations, at the university, winter semester 1841-42*], The Royal Library, Copenhagen, NkS 2778, 4° Box No.4, folder named "Practisk Chemie eller Anviisning i Konsten at indsamle og anvende chemiske Erfaringer 1841-42".

Zeise, W. C. (1841-42b)*, *For forelæsninger angaaende: Anvisning i practisk Chemie ell. Konsten at indsamle og anvende ch. Erfaringer i Almindelighed* (*Forel. ov. den ch.*

Experimenterkonst.) [Margin notes: *med specielle Anvisninger i chemist Undersøgelse over et Udvalg af medicinske, pharmaceutiske, techniske, okonomiske og agronomiske Gjenstande, samt i Tilvirkning af chemiske Agentier*] [En: *For lectures concerning: Instruction in practical chemistry or the art of acquiring and applying chemical experiences in general (lectures on the art of chemical experiments* [Margin notes: *with special instructions in chemical investigation regarding a selection of medical, pharmaceutical, technical, economic, and agronomical matters, including the production of chemical agents*], The Royal Library, Copenhagen, NkS 2778, 4° Box No.4, folder named "Practisk Chemie eller Anviisning i Konsten at indsamle og anvende chemiske Erfaringer 1841-42".

Zeise, W. C. (1843)*, *Collegium over practisk Chemie, eller Konsten at indsamle og anvende chemiske Erfaringer.* [Margin notes, possibly not Zeise's: *Trykt i Triers Archiv f. Pharmacie I* [referring to Zeise (1844) in my bibliography] [En.: *Colloquium on practical chemistry, or on the art of acquiring and applying chemical experiences* [Margin notes, possibly not Zeise's: *Published in Trier's Archiv f. Pharmacie* [referring to Zeise (1844) in my bibliography], The Royal Library, Copenhagen, NkS 2778, 4° Box No.4, folder named "Praktisk Chemi, Triers Archic f. Ph. I 1843".

Zeise, W.C. (1843-44), *Chemiens Hovedlærdomme* (*Vintersemestret 1843-44*) [Margin notes: *Ledetraad ved halvaarige Foredrag af den rene Chemie, af Z. Vintersemestret 1844-45*] [En.: *The main doctrines of chemistry* (*Winter semester 1843-44*) [Margin notes: *A guide for the half-yearly lecture on pure chemistry, by Z. Winter semester 1844-45*], The Royal Library, Copenhagen, NkS 2778, 4° Box No.4, folder named "Chemiens Hovedlærdomme, I Bd, 1839".

Zeise, W.C. 1844, "Af et endnu utrykt Skrift: "Anvisning i practisk Chmie eller Konsten at indsamle og anvende chemiske Erfaringer"", *Triers Archiv for Pharmacie,* vol. 1, pp. 1-9.

Zeise, W.C. 1847, *Haandbog i de organiske Stoffers almindelige Chemie,* , Kbh.

Ørsted, H.C. 1820, *Læresætninger af den nyere Chemie,* Andreas Seidelins Forlag, Kjøbenhavn.

Ørsted, H.C. 1920 [1848], "Mindreskrift over W.C. Zeise", in Vol. II, Meyer (ed) 1920, pp.555-568

*Undated original manuscripts are dated according to their folder's dating.

Appendix A

Scharling's table of *Værdital*

Chemiske Proportioner. 25

Paa en lignende Maade ere følgende Tal fundne:

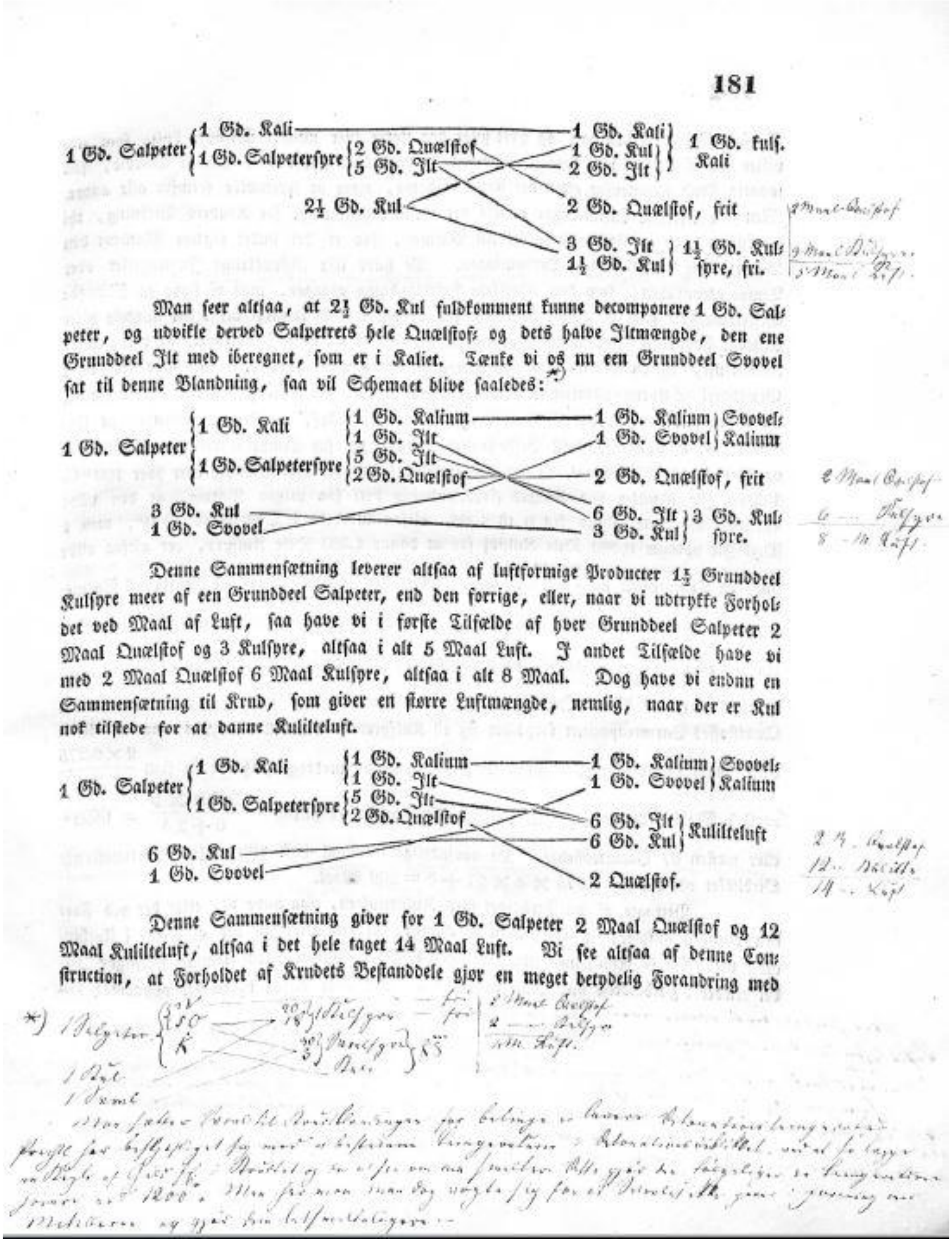
1. Ilt	100,000	28. Kobolt	368,991
2. Brint	62,398	29. Nikkel	369,675
3. Quælstof	88,518	30. Zink	403,226
4. Svovl	201,165	31. Kadmium	696,767
5. Phosphor	196,143	32. Bly	1294,498
6. Chlor	221,325	33. Tin	735,296
7. Brom	489,153	34. Wismuth	886,920
8. Jod	789,750	35. Kobber	395,695
9. Fluor	116,900	36. Uran	2711,358
10. Kulstof	76,438	37. Quiksølv	1265,822
11. Bor	136,204	38. Sølv	1351,607
12. Kiesel	277,312	39. Palladium	665,899
13. Kalium	489,916	40. Rhodium	651,387
14. Natrium	290,897	41. Iridium	1233,499
15. Lithium	80,375	42. Platin	1233,499
16. Barium	856,880	43. Guld	1243,013
17. Strontium	547,285	44. Osmium	1244,487
18. Calcium	256,019	45. Titan	303,662
19. Magnesium	158,353	46. Tantal	1153,715
20. Aluminium	171,166	47. Wolfram	1183,000
21. Beryllium	331,261	48. Molybdæn	598,520
22. Yttrium	402,514	49. Vanadin	855,840
23. Zirconium	420,201	50. Chrom	351,815
24. Thorium	744,900	51. Antimon	806,452
25. Cerium	574,796	52. Tellur	801,760
26. Mangan	345,887	53. Arsenik	470,042
27. Jern	339,205	54. Selen	494,583

Naar altsaa f. Ex. Sølv forener sig med Svovl, saa forbinder nøiagtigen 201 Dele (Lod, Pund) Svovl sig med 1351 Dele Sølv. Ethvert Overskud af Svovl eller Sølv vil ikke gaae ind i Foreningen. Jern derimod kan forbinde sig med Ilt i to

Source: Scharling, E.A. 1837, *F. Wöhler's Grundrids af Chemien: Uorganisk Chemie,* Reitzel, Kbh. p.25

Appendix B

Forchhammer on gunpowder



181

1 Gd. Salpeter { 1 Gd. Kali — 1 Gd. Kali; 1 Gd. Salpetersyre { 2 Gd. Qvælstof, 5 Gd. Ilt } — 1 Gd. Kul, 2 Gd. Ilt } 1 Gd. kulſ. Kali
2½ Gd. Kul — 2 Gd. Qvælstof, frit
3 Gd. Ilt, 1½ Gd. Kul } 1½ Gd. Kulsyre, fri.

Man seer altsaa, at 2½ Gd. Kul fuldkomment kunne decomponere 1 Gd. Salpeter, og udvikle derved Salpetrets hele Qvælstof- og dets halve Iltmængde, den ene Grunddeel Ilt med iberegnet, som er i Kaliet. Tænke vi os nu een Grunddeel Svovel sat til denne Blanding, saa vil Schemaet blive saaledes: *)

1 Gd. Salpeter { 1 Gd. Kali { 1 Gd. Kalium, 1 Gd. Ilt }; 1 Gd. Salpetersyre { 5 Gd. Ilt, 2 Gd. Qvælstof } } — 1 Gd. Kalium, 1 Gd. Svovel } Svovelkalium
3 Gd. Kul, 1 Gd. Svovel — 2 Gd. Qvælstof, frit
6 Gd. Ilt, 3 Gd. Kul } 3 Gd. Kulsyre.

Denne Sammensætning leverer altsaa af luftformige Producter 1½ Grunddeel Kulsyre meer af een Grunddeel Salpeter, end den forrige, eller, naar vi udtrykke Forholdet ved Maal af Luft, saa have vi i første Tilfælde af hver Grunddeel Salpeter 2 Maal Qvælstof og 3 Kulsyre, altsaa i alt 5 Maal Luft. I andet Tilfælde have vi med 2 Maal Qvælstof 6 Maal Kulsyre, altsaa i alt 8 Maal. Dog have vi endnu en Sammensætning til Krud, som giver en større Luftmængde, nemlig, naar der er Kul nok tilstede for at danne Kulilteluft.

1 Gd. Salpeter { 1 Gd. Kali { 1 Gd. Kalium, 1 Gd. Ilt }; 1 Gd. Salpetersyre { 5 Gd. Ilt, 2 Gd. Qvælstof } } — 1 Gd. Kalium, 1 Gd. Svovel } Svovelkalium
6 Gd. Kul, 1 Gd. Svovel — 6 Gd. Ilt, 6 Gd. Kul } Kulilteluft
2 Qvælstof.

Denne Sammensætning giver for 1 Gd. Salpeter 2 Maal Qvælstof og 12 Maal Kulilteluft, altsaa i det hele taget 14 Maal Luft. Vi see altsaa af denne Construction, at Forholdet af Krudets Bestanddele gjør en meget betydelig Forandring med

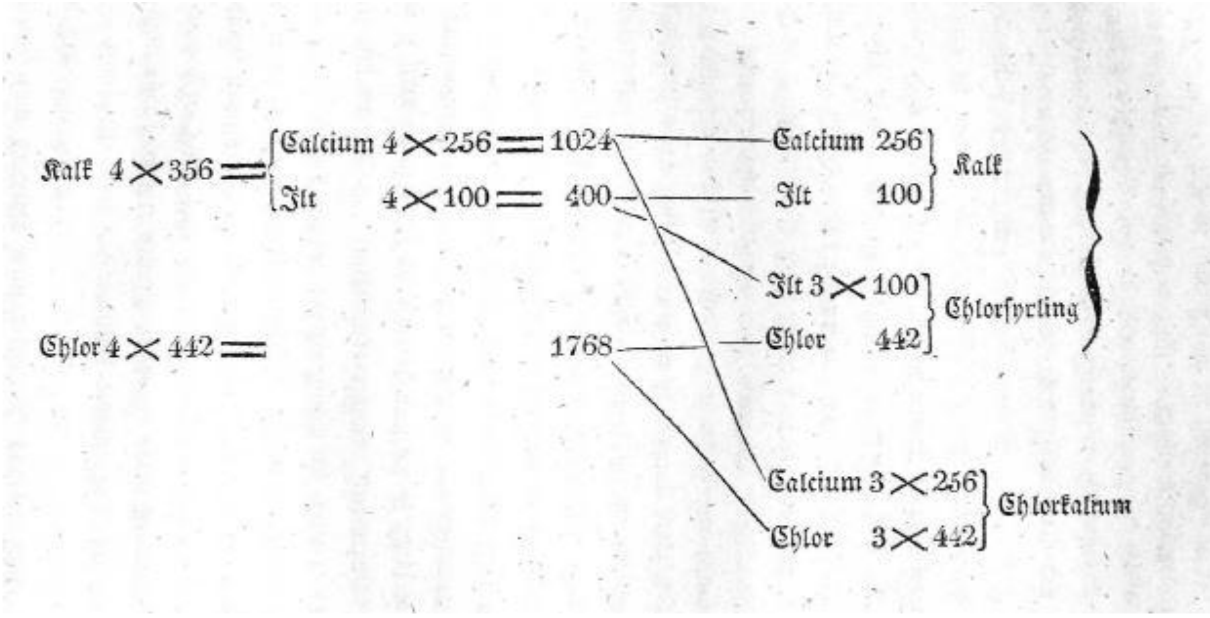
*) [illegible]

Source: Forchhammer, J.G. 1830-31b, *Ledetraad ved Forelæsningerne over Chemie ved den kongelige militaire Høiskole, 1830-31:2nden Deel (den bogtrykte Part) af I Hæfte. Den Uorganisk Chemie*, , Kbh. p.181

Appendix C

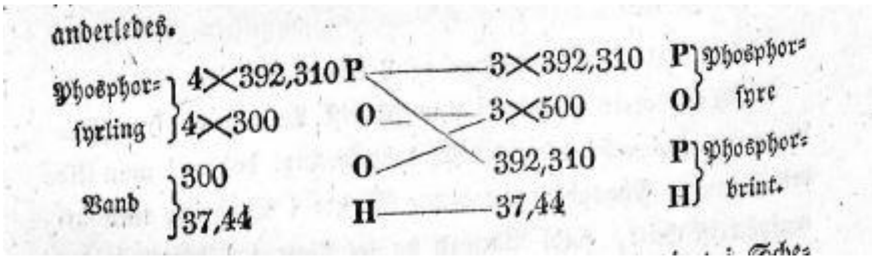
Forchhammer's didactic schemata

Illustration 1



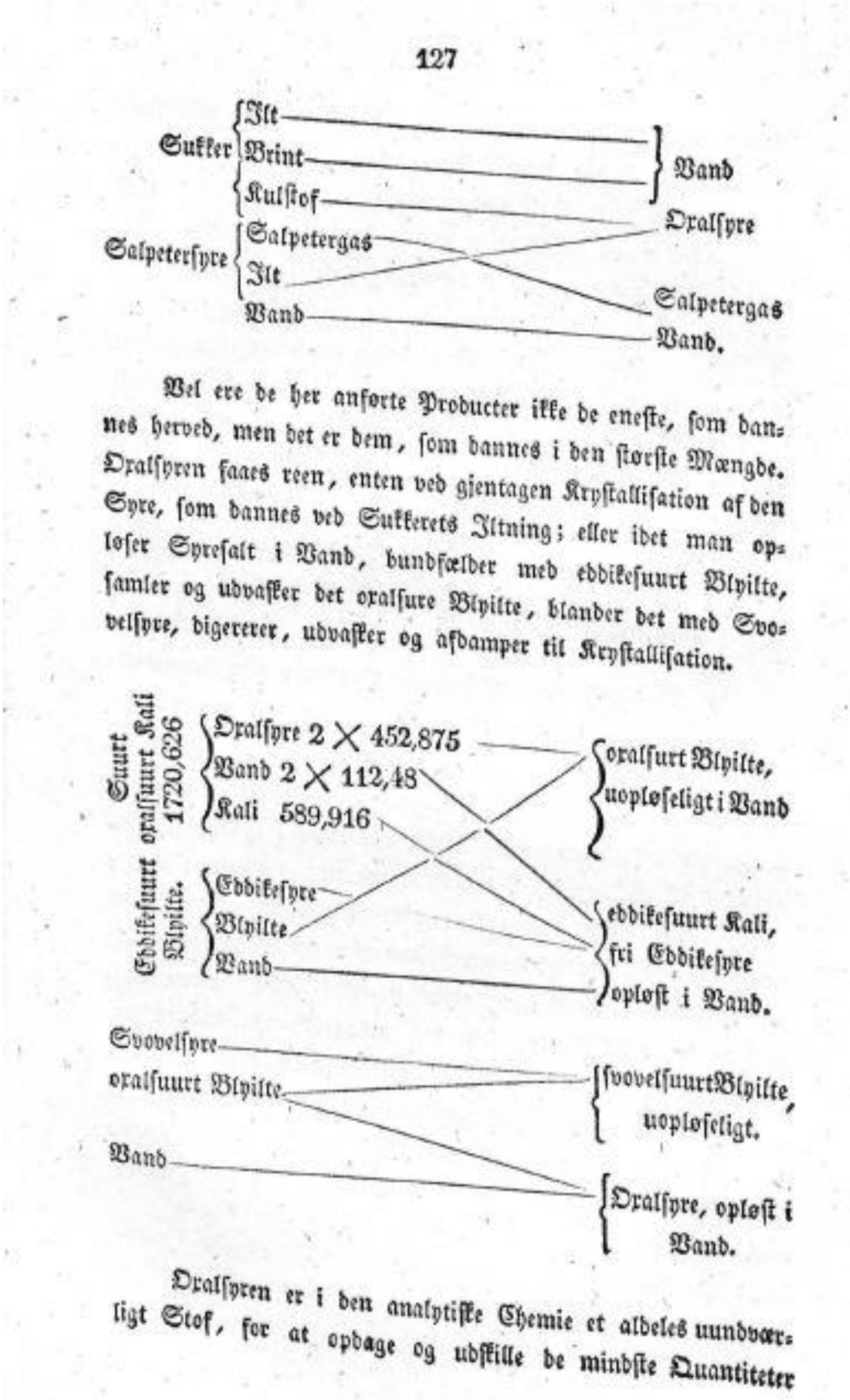
Source: Forchhammer, J.G. 1834-35, *Lærebog i Stoffernes almindelige Chemie : 1-2. H. (1 Vol.),* , Kbh. p.89

Illustration 2



Source: Forchhammer, J.G. 1834-35, *Lærebog i Stoffernes almindelige Chemie : 1-2. H. (1 Vol.),* , Kbh. p.98

Illustration 3


127

Sukker: Ilt, Brint, Kulstof — Vand, Oxalsyre
Salpetersyre: Salpetergas, Ilt, Vand — Salpetergas, Vand.

Vel ere de her anførte Producter ikke de eneste, som dannes herved, men det er dem, som dannes i den største Mængde. Oxalsyren faaes reen, enten ved gjentagen Krystallisation af den Syre, som dannes ved Sukkerets Iltning; eller idet man opløser Syresalt i Vand, bundfælder med eddikesuurt Blyilte, samler og udvasker det oxalsure Blyilte, blander det med Svovelsyre, digererer, udvasker og afdamper til Krystallisation.

Suurt oxalsuurt Kali 1720,626: Oxalsyre 2 × 452,875; Vand 2 × 112,48; Kali 589,916
Eddikesuurt Blyilte: Eddikesyre, Blyilte, Vand
— oxalsurt Blyilte, uopløseligt i Vand
— eddikesuurt Kali, fri Eddikesyre opløst i Vand.

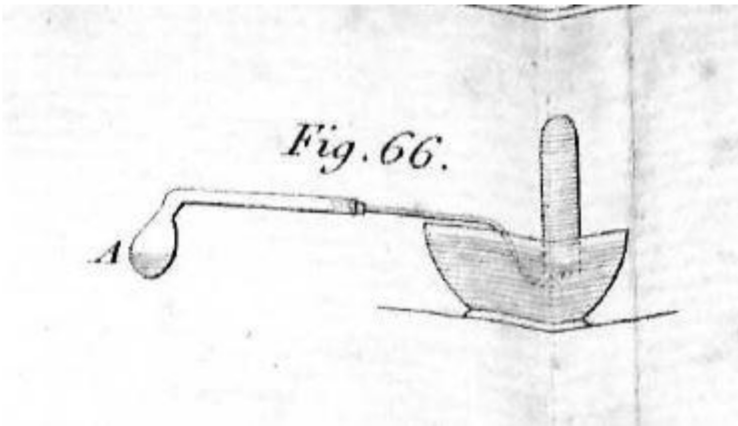
Svovelsyre, oxalsuurt Blyilte, Vand
— svovelsuurt Blyilte, uopløseligt.
— Oxalsyre, opløst i Vand.

Oxalsyren er i den analytiske Chemie et aldeles uundværligt Stof, for at opdage og udskille de mindste Quantiteter

Source: Forchhammer, J.G. 1834-35, *Lærebog i Stoffernes almindelige Chemie : 1-2. H. (1 Vol.),* , Kbh. p.127

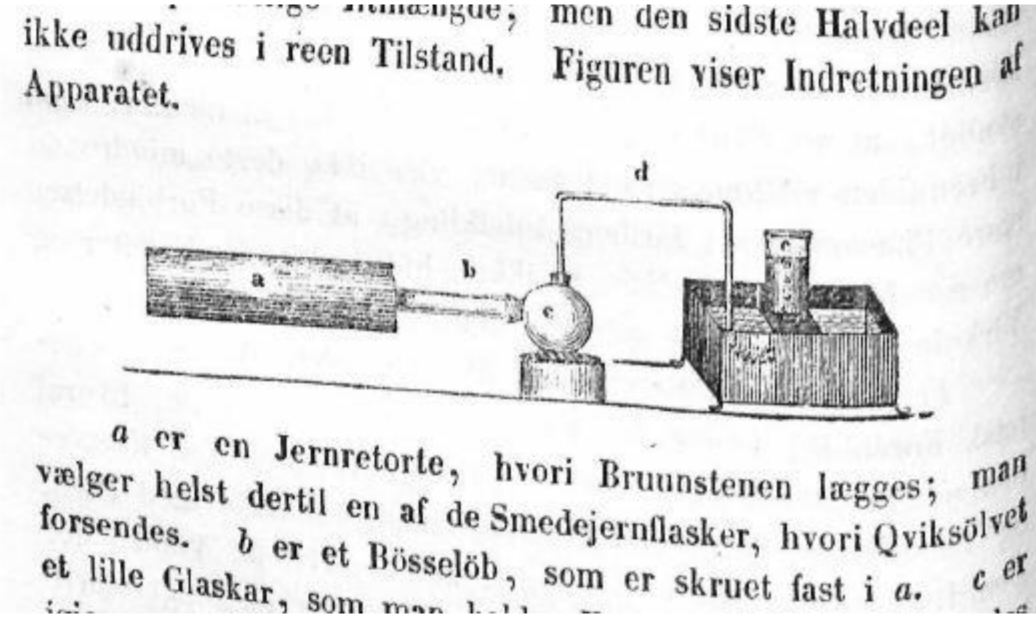
Appendix D

Zeise's illustration for acquiring oxygen



Source: Zeise, W.C. 1829, *Udførlig Fremstilling af Chemiens Hovedlærdomme saavel i theoretisk som practisk Henseende*, Fr. Brummer, Kbh. Table IV (at the back of the work)

Forchhammer's illustration for acquiring oxygen


men den sidste Halvdeel kan ikke uddrives i reen Tilstand. Figuren viser Indretningen af Apparatet.

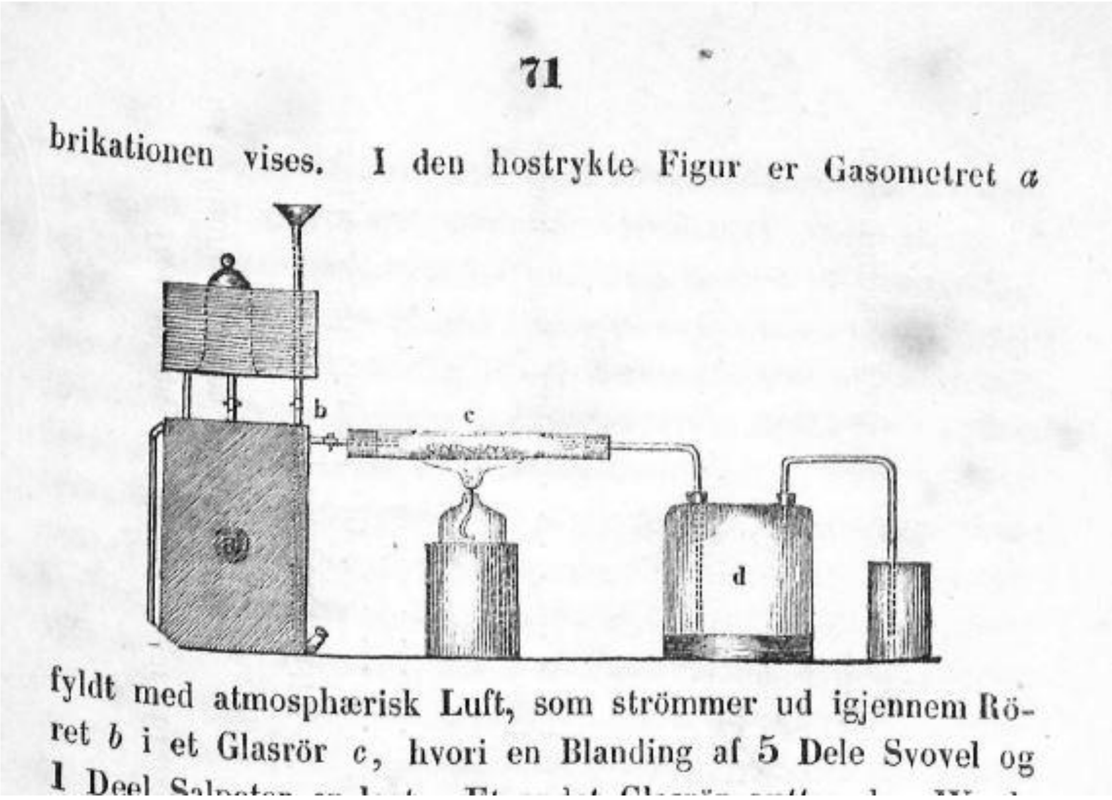
a er en Jernretorte, hvori Bruunstenen lægges; man vælger helst dertil en af de Smedejernflasker, hvori Qviksölvet forsendes. *b* er et Bösselöb, som er skruet fast i *a*. *c* er et lille Glaskar, som man

Source: Forchhammer, J.G. 1842, *Lærebog i Stoffernes almindelige Chemie : D. 1. De enkelte Radikalers almindelige Chemie*, C. A. Reitzel, Kbh. p.2

Appendix E

Forchhammer's description of sulphuric acid

Illustration 1

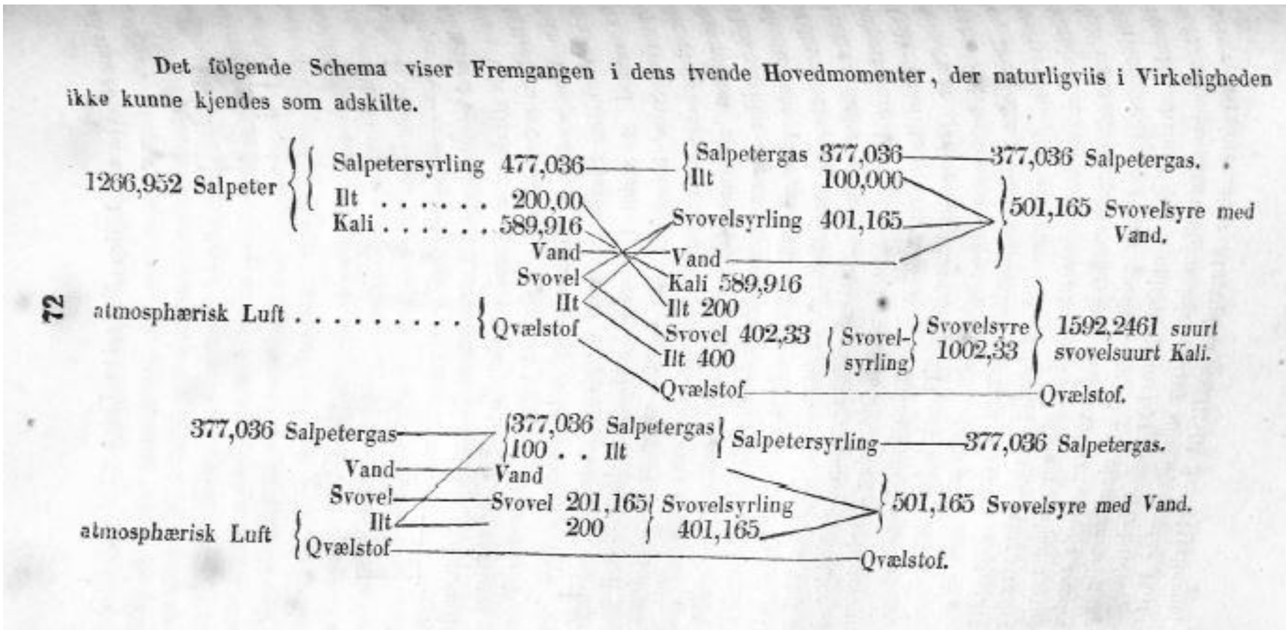

71

brikationen vises. I den hostrykte Figur er Gasometret *a*

fyldt med atmosphærisk Luft, som strömmer ud igjennem Rö-
ret *b* i et Glasrör *c*, hvori en Blanding af 5 Dele Svovel og
1 Deel

Source: Forchhammer, J.G. 1842, *Lærebog i Stoffernes almindelige Chemie : D. 1. De enkelte Radikalers almindelige Chemie*, C. A. Reitzel, Kbh. p.71

Illustration 2


Det fölgende Schema viser Fremgangen i dens tvende Hovedmomenter, der naturligviis i Virkeligheden ikke kunne kjendes som adskilte.

Source: Forchhammer, J.G. 1842, *Lærebog i Stoffernes almindelige Chemie : D. 1. De enkelte Radikalers almindelige Chemie,* C. A. Reitzel, Kbh. p.72

Appendix F

Forchhammer's instructions for the quantitative analysis of gunpowder

64

Analyse af Krud.

A. 1. 5 Grammer Krud udvadskes med Vand.

2. Opløsningen bundfældes med salpetersk. Sølv: = Chlorsølv.

B. 1. 5 Grammer Krud udvadskes med Vand.

2. Det Uopløste opvarmes i et Glasrør med Brint: tilbagebliver Kul.

3. Opløsningen afdampes til Tørhed, smeltes ved svag Varme, veies: = Salpeter.

4. Saltet glødes, opløses i Vand, overmættes med Salpetersyre, bundfældes med salpetersk. Sølv: = Chlorsølv.

C. 1. 5 Grammer Krud blandes med 2½ Gram Salpeter, 5 Grammer kulsk. Kali og 20 Grammer Chlornatrium, glødes og opløses i Vand.

2. Opløsningen overmættes med Chlorbrintesyre, og bundfældes med Chlorbaryum: = svovelsk. Baryt.

Beregning.

0,008 Gr. Chlorsølv A. 2	=	0,003	Clornatrium.
0,532 Gr. Chlorsølv B. 4	=	0,455	chlorsuurt Kali.
4,540 Gr. svovelsk. Baryt C. 2	=	0,625	Svovel.
Kul	=	0,800	Kul.
3,575—0,458 Gr. Salpeter	=	3,117	Salpeter.
		5,	

A. Denne Deel af Analysen tjener ikkun til at undersøge Salpeterets Reenhed, og falder altsaa bort, naar det til Krudet anvendte Salpeter har været frit for Chlornatrium.

B. 2. For at sublimere Svovelet fuldkomment fra Kullet, bringer man en veiet Mængde af Svovel og Kul i et Glasrør, som sættes i Forbindelse med en Flaske, hvori der udvikles Brint; man opvarmer Røret med Spiritus-Lampen, medens der strømmer Brint over Pulveret. Svovelet forflygtiges let i denne Strøm, og skulde der ogsaa blive lidet Svovel hængende i Røret, saa kan man siden let drive det ud, ved at hælde Røret lidet, medens Stedet, hvor Svovelet sidder, opvarmes, og den atmosphæriske Luft strømmer igjennem.

3. Ved at smelte Salpeteret, maa man være meget forsigtig, at det ikke bliver rødglødende, hvorved man vilde lide et Tab.

4. Ved Glødningen forvandles den hele Mængde chlorsuurt Kali til Chlorkalium; men man maa ikke gløde for svagt, og naar Mængden er nogenlunde betydelig, ikke kortere end en halv Time.

C. Man indseer let, at Hensigten ved denne Operation er at forvandle Svovelet til Svovelsyre. For at gjøre det uden Tab, sættes det kulsure Kali til, hvorved først dannes Svovelkalium, som siden iltes af Salpeterets Ilt. Den store Mængde Chlornatrium, som man sætter til, formindsker Forpufningens Voldsomhed saa meget, at Massen kan ophedes i en Platindigel over Lampen, og brænder meget rolig og uden Tab.

Jeg har forudsat ved denne Analyse, at der var chlorsuurt Kali tilstede i Krudet; dette er vistnok et yderst sjeldent Tilfælde, men enhver vil vide at udelade denne Deel af Undersøgelsen, naar intet chlorsuurt Kali forekommer deri.

Source: Forchhammer, J.G. 1831b, *Ledetraad ved Forelæsningerne over Chemie ved den kongelige militaire Høiskole, 1831: III Hefte, Den analytiske Chemie*, , Kbh. pp.64-65

Recent RePoSS issues

#30 (2014-12) **Hanne Andersen**: "Responsible Conduct of Research: Collaboration" (Preprint)

#31 (2014-12) **Mads Ingersgaard Jørgensen**: "Evolution, kognition og religion: Religiøse idéer i evolutionært og kognitivt perspektiv" (Masters thesis)

#32 (2015-10) **Mie Johannesen**: "Studieretningsprojekter i matematik og historie: Kvalitative og kvantitative undersøgelser samt en konstruktiv matematikhistorisk tilgang til gode samspil" (Masters thesis)

#33 (2015-10) **Carina Tangsgaard**: "Samarbejde i bioinformatik: Et casestudie i hvordan man overvinder kløften mellem subdisciplinerne" (Masters thesis)

#34 (2016-2) **Sarah Kassem Kaltoft**: "Sciencecentre & sundhedsfremme: En empirisk undersøgelse af, hvordan projektet PULS, et samarbejde mellem Experimentarium og Steno Center for Sundhedsfremme, kan motivere folk til at være fysisk aktive" (Masters thesis)

#35 (2016-2) **Kristian H. Nielsen**: "The practice and politics of integrated science teaching in the global Cold War" (Preprint)

#36 (2016-2) **Jeanette Gedsø**: "Women's limited role in science conditioned by historical and cultural factors — with a focus on Marie Curie and her career in natural science " (Bachelor project)

#37 (2016-2) **Bircan Aykurt**: "Surveying nanoscientists' communication activities and online behavior" (Masters thesis)

#38 (2016-4) **Henrik Kragh Sørensen**: "Kildecentreret matematikhistorie i praksis: En kort indføring i matematikhistorisk metode" (Preprint)

#39 (2016-11) **Sujeevan Sivasundaram**: "Interpreting Quantum Mechanics" (Masters thesis)

#40 (2017-2) **Kurt Møller Pedersen**: "The Velocity of Light and the color Changes of Jupiter's Satellites" (Article)

#41 (2017-7) **Carsten Sønderskov Jørgensen**: "Christian Horrebows observationer af Solen: En analyse af hans observationsprotokoller og artikler med henblik på en forståelse af de anvendte metoder" (Masters thesis)

#42 (2018-3) **Louise Kobek Thorsen**: "Kratluskernes kognitive praksis: En udvikling af miljøbevægelser i 1980'ernes Danmark" (Masters thesis)

#43 (2018-3) **Henrik Kragh Sørensen and Line Edslev Andersen**: "Mapping Social Aspects of Mathematical Knowledge Production" (Book chapter)

#44 (2018-8) **Marcus Lee Naldal**: "Textbooks and Knowledge Infrastructures of Copenhagen chemistry, c. 1820-1850" (Masters thesis)

This list is up-to-date as of August 15, 2018. The full list of RePoSS issues can be found at `www.css.au.dk/reposs`.

RePoSS (Research Publications on Science Studies) is a series of electronic publications originating in research done at the Centre for Science Studies, University of Aarhus.

The publications are available from the Centre homepage (www.css.au.dk/reposs).

ISSN 1903-413X

Centre for Science Studies
University of Aarhus
Ny Munkegade 120, building 1520
DK-8000 Aarhus C
DENMARK
www.css.au.dk

Faculty of Science
Department of Science Studies
AARHUS UNIVERSITET