A Bibliographical Framework for Citation Analysis of Isaac Newton's Alchemical Manuscripts

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ABSTRACT

Since 2005, the Chymistry of Isaac Newton *project has encoded digital editions of Newton's alchemical manuscripts in Text Encoding Initiative-XML (TEI-XML). While encoding, team members have traced Newton's numerous citations to alchemical sources to learn more about how Newton used sources and to date his manuscripts. This article compares the old and new frameworks for encoding these citations to demonstrate the need for a bibliographically informed approach to encoding. The new framework accounts for the complexities in the publication histories of alchemical sources and Newton's own inconsistencies and errors in citations which enables the* terminus post quem *dating of manuscripts as well as the analysis of Newton's use of sources. Preliminary analyses of Newton's alchemical studies based on the encoded citations reveal insights into the development of his notetaking habits, the incorporation of sources into his corpus, and patterns in his reliance on specific sources over time.*

> Nam Lapidis ignis interior partim innatus partim more philosopico [sic] additus est: uniuntur quippe illi duo et introrsum coeunt quia homogenei sunt. ib. p. 72. (Cambridge, King's College Library, Keynes MS. 56, charta 3*v*)[1]

THE ABOVE PASSAGE FROM CAMBRIDGE, KING'S COLLEGE LIBRARY, Keynes MS. 56 is one of thousands of passages Sir Isaac Newton quoted or paraphrased in his notes on alchemy taken from print and manuscript

1. "For the interior fire of the stone is partly natural and partly added in a philosophical manner. Of course, the two are united and come together inwardly because they are homogenous. ibidem p. 72." [my translation]

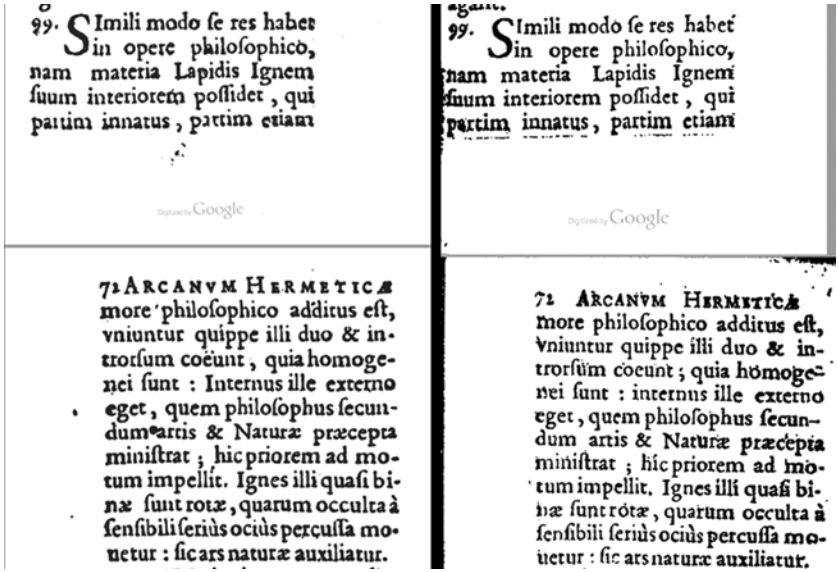
alchemical literature.[2] It can be traced to the *Arcanum hermeticae philosophiae* by Jean d'Espagnet, who, in addition to his alchemical pursuits, was a lawyer from Bordeaux who eventually became the president of the Parliament of Bordeaux among other positions (Willard [1999] (2018), xiii–xiv).[3] But which edition of the *Arcanum hermeticae philosophiae* might Newton have been using? There are at least ten editions and reissues of the *Arcanum hermeticae philosophiae* appearing in French, English, and Latin printed before Newton's death in 1727. The original Latin tract was initially published in 1623 in Paris by Nicholas Buon alongside the *Enchiridion physicae restitutae*, another alchemical tract by d'Espagnet, and the two works were subsequently often published together, with the *Enchiridion physicae restitutae* usually appearing first.[4] In both texts, d'Espagnet, like many alchemists, concealed his authorship in an anagram: "Spes Mea in Agno" (My faith is in the lamb) for the *Enchiridion physicae restitutae* and "Penes Nos Unda Tagi" (I come from the moving waters of the Tagus).[5] In Latin, the *Arcanum hermeticae philosophiae* was printed after 1623 as part of the 1642 edition of *Enchiridion physicae restitutae* (Parisiis: n.p.) where *Arcanum hermeticae philosophiae* has a separate title page dated 1638; another 1642 edition of *Enchiridion physicae restitutae* (Parisiis: Apud viduam Nic. de Sercy), which also has a separate title page for *Arcanum hermeticae philosophiae* dated 1647; a 1647 Rouen edition of both texts together; the 1653 *Bibliotheca chemica contracta* compiled by Nathan Albineus (Genevae: Sumpt. Ioannis Ant. & Samuelis de Tournes) plus its 1654 reissue and subsequent edition in 1673 (Genevae: Sumpt. I. Ant. & Samuelis De Tournes); and the second volume of Jean-Jacques Manget's 1702 *Bibliotheca chemica curiosa* (Genevae: Sumpt. Chouet,

2. This essay is an expansion on a paper presented at the 2022 USTC conference "Print & Manuscript". My thanks go to the organizers and attendees for their feedback. I am especially grateful as well to a reviewer of this article for their generous, detailed, and constructive feedback.
3. For a more detailed account of d'Espagnet's life, see Willard [1999] 2018, xiii–xxiii.
4. See Espagnet 1623.
5. Willard notes that "Spes Mea in Agno" echoes the authorial anagram of Michael Sendivogius: "Divi Leschi Genus Amo", meaning "I love the order of the lamb of God" [Willard's translation] ([1999] 2018, xxiii). Sendivogius was another alchemist admired by both d'Espagnet and Newton (Willard [1999] 2018, xxiii; Newman 2019, 182). "Penes Nos Unda Tagi" references d'Espagnet's Spanish heritage. "d'Espagnet" means "from Spain", and the Tagus is one of Spain's major rivers (Willard [1999] 2018, xiii).

G. De Tournes, Cramer, Perachon, Ritter, & S. De Tournes).[6] In French, the *Arcanum hermeticae philosophiae* and *Enchiridion physicae restitutae* were published together in 1651 in the same volume under the titles *L'ouvrage secret de la philosophie d'Hermez* and *La philosophie naturelle restablie en sa purete*, respectively (Paris: chez Edme Pepingué).[7] In English, they were published separately. The *Arcanum hermeticae philosophiae* was translated as *Arcanum: or, The grand Secret of Hermetick Philosophy* by Elias Ashmole (though under the pseudonymous anagram "James Hasolle") and was included in the *Fasciculus Chemicus* (London: Printed by J. Flesher for Richard Mynne, 1650), while the *Enchiridion physicae restitutae* was published as *Enchyridion Physicae Restitutae; or, The Summary of Physicks Recovered* (London: W. Bentley [. . .] to be sold by W. Sheares at the Bible, and Robert Tutchein at the Phenix, in the New-Rents in S. Pauls Church-Yard, 1651).[8]

The inclusion of a page number in Newton's citation — p. 72 — would appear to allow us to determine the edition he was referencing from all these possible editions since the information likely appears on different pages in different editions. Unfortunately, the bibliographical situation is not so simple. There are two possible editions where this quote appears on p. 72, with one seeming to be a line-by-line reprint of the other. These are the two Parisian editions in Latin where the *Enchiridion physicae restitutae* is dated 1642 and the *Arcanum hermeticae philosophiae* has a separate title page dated 1638 or 1647. As seen in Figure 1 below, the same content appears on the same numbered pages and even on the same lines — hence the term line-by-line reprint.[9] Further, the catalog of Newton's library by John Harrison contains

6. See Espagnet 1642a, Espagnet 1642b, Espagnet 1647, Albineus 1653, Albineus 1654, Albineus 1673, and Manget 1702.
7. See Ashmole 1650, Espagnet 1651b.
8. See Espagnet 1651a.
9. Reprinting in this manner was likely advantageous for printers. By using a prior edition (either their own or that of another printer) and copying the setting of type, they could easily estimate ("cast off") the number of sheets needed for the new edition and calculate the necessary amount of paper, the greatest upfront cost for printing. Further, work could have proceeded more efficiently since type setting could begin from any point in the book and multiple sections could be set at once (Gaskell [1972] 1995, 41). The *Arcanum hermeticae philosophiae* in Albineus 1673 is also a line-by-line reprint of the *Arcanum hermeticae philosophiae* in Albineus 1653.


99. Simili modo ſe res habet in opere philoſophico, nam materia Lapidis Ignem ſuum interiorem poſſidet, qui partim innatus, partim etiam

72 ARCANVM HERMETICÆ more philoſophico additus eſt, vniuntur quippe illi duo & introrſum coëunt, quia homogenei ſunt: Internus ille externo eget, quem philoſophus ſecundum artis & Naturæ præcepta miniſtrat; hic priorem ad motum impellit. Ignes illi quaſi binæ ſunt rotæ, quarum occulta à ſenſibili ſeriùs ociùs perçuſſa mouetur: ſic ars naturæ auxiliatur.

99. Simili modo ſe res habet in opere philoſophico, nam materia Lapidis Ignem ſuum interiorem poſſidet, qui partim innatus, partim etiam

72 ARCANVM HERMETICÆ more philoſophico additus eſt, vniuntur quippe illi duo & introrſum coëunt; quia homogenei ſunt: internus ille externo eget, quem philoſophus ſecundum artis & Naturæ præcepta miniſtrat; hic priorem ad motum impellit. Ignes illi quaſi binæ ſunt rotæ, quarum occulta à ſenſibili ſeriùs ociùs percuſſa mouetur: ſic ars naturæ auxiliatur.

Figure 1. Page 72 of the Arcanum hermeticae philosophiae in (left to right) Enchiridion physicae restitutae (Parisiis: n.p., 1642) and Enchiridion physicae restitutae (Parisiis: viduam Nic. de Sercy, 1642). Screenshots are from Google Books from the Bavarian State Library and the British Library, respectively.

no record of either edition.[10] So which edition did Newton use given this conundrum caused by the source's publication history?

The dilemma faced here of tracking down the right edition is one applicable to all the citations in Newton's alchemical corpus. This corpus is extensive, consisting of his reading notes, manuscript copies he made of alchemical texts, and experimental notebooks that he created starting in the 1660s (NEWMAN 2019, 89).[11] Newton may be less well-known for his alchemical or "chymical" studies, but he dedicated significant time to it as demonstrated by his more than 120 extant manuscripts.[12]

These studies obviously required sources, and there is a whole universe of potential sources that could be referenced by Newton's citations. To support his alchemical, religious, scientific, and mathematical studies and other interests,

10. See HARRISON 1978.
11. See also WESTFALL 1980, which is a comprehensive biography of Newton.
12. The Newton Project provides descriptions and/or transcriptions of Newton's manuscripts and letters in all areas of his work. See ILIFFE and MANDELBROTE, n.d.

Newton accumulated a library of at least 2,100 volumes, a large portion of which still survives today and bears witness to his use through some marginalia and extensive dog-earing of pages (Harrison 1978, 1, 15, 25–26).[13] Harrison categorizes 9.5% of the 1,752 titles as alchemical or chemical in his catalog of Newton's library (1978, 59). Of course, as with all private libraries, neither Newton's books that have survived to the present day nor his library at his death fully represent his reading. On one hand, Newton certainly borrowed books from others, including alchemical texts (Harrison 1978, 6; Figala et al. 1992, 159n87, 160; Newman 2019, 182n3). On the other hand, while Newton was at Trinity College Cambridge between 1661 and 1696, he would have had access to Trinity's library, which totaled 3,000–4,000 volumes in addition to the 10,000–12,000 volumes at the Public Library of the University of Cambridge (Harrison 1978, 6). In addition to these print sources, Newton could have created or borrowed manuscript copies of alchemical texts as well.

Since 2005, the *Chymistry of Isaac Newton* project team has worked extensively with Newton's alchemical manuscripts.[14] The team has worked to provide access to digitized copies of these alchemical manuscripts as well as to create diplomatic and normalized digital editions of each manuscript using TEI-XML (Text Encoding Initiative-XML). These digital editions provide more readable and searchable access to Newton's alchemical corpus. In addition, the project has focused on assembling textual, bibliographical, and material evidence to date Newton's alchemical manuscripts. As opposed to his extensive surviving correspondence, Newton's alchemical manuscripts are undated, and so analyses to put them in chronological sequence will help uncover the evolution of Newton's alchemical thought.

The methods currently being explored by the project to date Newton's manuscripts are ink, watermark, paleographic, and citation analysis. The ink and watermark analyses group manuscripts via matching the composition of elements in their inks or matching the watermarks in their paper, following the logic that Newton may have used the same batch of ink or stack of paper for manuscripts written around the same time. If one or more of the grouped manuscripts are dated, such as from Newton's

13. Newton used the corners of pages in his dog-earing to point to specific words, lines, or passages of interest (Harrison 1978, 25). For more detailed information on Newton's library and its dispersal after Newton's death, see Harrison 1978.
14. For the *Chymistry of Isaac Newton* website, see Chymistry of Isaac Newton n.d. For information about the Text Encoding Initiative and their encoding guidelines, see TEI Consortium n.d.-b.

correspondence, then the other manuscripts may also date from around the same period. Paleographic analysis is limited at the moment to Newton's style of writing certain symbols or spelling of certain words, such as the Saturn symbol (♄), but it is useful for estimating whether a manuscript is from earlier or later in Newton's alchemical career.

One of the project's main methods for dating Newton's alchemical manuscripts is to use his extensive citations to establish a *terminus post quem* (TPQ) for each manuscript — the earliest date by which it could have been completed — since a manuscript cannot have been finished before the publication date of its latest print source.[15] For example, if a manuscript has a citation to a source published in 1686, the manuscript cannot have been completed any earlier than 1686. Identifying the sources referenced by these citations provides the necessary data to perform these TPQ calculations and indicates the authors and works Newton was using in his alchemical research. Therefore, a major task for the *Chymistry* project is encoding these citations in order to: 1) date Newton's manuscripts, 2) analyze Newton's usage of specific authors and works in these texts, and 3) furnish the digital edition's readers with accurate information about Newton's source for each citation.

Tracing each citation to its proper source is not a simple task, however, as the initial example of Newton's reference to d'Espagnet demonstrates. In this article, I will discuss the framework for encoding citations that I developed with the *Chymistry* team, its application to the variety of citation forms that Newton used when creating his personal alchemical texts, and preliminary findings from the citation analysis of these texts.[16] I argue that this framework

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15. Funding for some of this research comes from the National Science Foundation grant award 2021012, "A Multidimensional Reconstruction of the Order of Composition of Historical Manuscripts from Textual and Material Evidence". For a demonstration of citation-based dating of Newton's Index Chemicus, see Allen 2019.

16. Current *Chymistry* team members are William R. Newman, John A. Walsh, Seth Cope, William G. Cowan, Michelle Dalmau, Wallace Hooper, Takatomo Inoue, Madeline Keyser, Joel Klein, Cassidy Polack, James R. Voelkel, and Alexandra Wingate. Bibliography and citation encoders past and present are Meagan Allen, Finch Collins, Seth Cope, Takatomo Inoue, Justina Kaiser, Madeline Keyser, Meridith Beck Mink, Cassidy Polack, Alexandra Wingate, and Amy Yarnell. My deepest thanks go to William Newman and Michelle Dalmau for encouraging me to redesign our citation encoding guidelines, as well as to the *Chymistry* team, particularly James Voelkel, Michelle Dalmau, William Newman, and Wallace Hooper, for their input in revising the new system.

is successful in accomplishing the three goals stated above because it takes into account the complex publishing histories of early modern texts, such as the two 1642 editions of the *Enchiridion physicae restitutae*/*Arcanum hermeticae philosophiae*, and the non-standardized and incomplete nature of many of Newton's citations.[17] The careful, bibliographically-sensitive encoding of these citations as part of the preparation of these texts for digital publication provides us with the base for new understandings of Newton and his alchemical work. Further, the framework proposed here could be extended to citations in materials created by individuals other than Newton and applied to understand their intellectual histories.

Encoding citations

Encoding citations has been a long process for the *Chymistry* project and has proceeded under two systems: an initial encoding system and the current encoding system. Before the current citation encoding system was developed in 2020, the *Chymistry* team used a simpler system for encoding citations in TEI.[18] While this system worked fairly well for some of the initial manuscripts encoded where citations with page numbers could be easily tracked to one source, it did not cover all potential situations. Other manuscripts featured less exact citations by Newton and citations where determining the exact source used was impossible (as with d'Espagnet). The simpler citation encoding system was not sufficient to date Newton's manuscripts or to trace how Newton's alchemical studies changed over time, and it needed to be revised. The current system was developed to account for these intricacies. In the following section, I describe the initial encoding system and the problems of applying it to "messy" citations.

17. I would like to thank the many librarians that have responded to my questions relating to alchemical texts or Newton's own copies of works in their collections, particularly the librarians of Trinity College Cambridge where the majority of Newton's library is held, Jason Dean and the librarians at the Linda Hall Library, and the British Library. Tracing these citations would not be possible without such generous help.
18. For the unfamiliar, TEI is an XML-based encoding language developed by and for humanities scholars for the encoding of humanities texts of all kinds including literature, poetry, drama, manuscripts, dictionaries, corpus linguistics, social science data, and many others. The use of a common XML element/attribute set and schema is designed to promote interoperability between different corpora of textual data. For more information on the development of TEI, see Cummings 2008.

Next, I outline the current encoding system and how the application of bibliographic notes and a four-level certainty framework to citations allowed the *Chymistry* team to account for the challenges inherent in Newton's citations. By specifying our certainty that the source was the one referenced by Newton's citation and providing additional information about complications in tracing the citation, the *Chymistry* project can finally date manuscripts, show what authors and works Newton used, and provide important information to readers of the digital edition.[19]

The initial citation encoding system

The initial system consisted of a bibliography of Newton's sources, whose entries were referenced by encoded in-text citations in the manuscript transcriptions, similar to standard bibliographies and in-text citations in modern academic literature.[20] The bibliography contained a series of entries with bibliographic information about each source: author, a short title, a quasi-facsimile transcription of the correct edition's title page, imprint information, and a link to either a full-text transcription or digitized copy of the book (i.e., text versus images). Both the bibliography and the citations were encoded in TEI-XML, the language used to create the *Chymistry* project's digital editions and many other scholarly digital editions. Like other XML languages, TEI uses elements and attributes to describe the data/text encoded. Elements, which are contained within angle brackets (< >), might be likened to nouns specifying what something is, while attributes are adjectives further describing or specifying those nouns.[21] Applied to the bibliography and citations, each bibliographic

19. In the sections discussing the initial and current encoding systems, I have tried to make the discussion as accessible as possible to those unfamiliar with XML and TEI. As a result, some footnotes have been added to provide additional technical explanation or detail to those interested.
20. This simpler encoding system and a more detailed description of the construction of the bibliography are also discussed in Beck Mink et al. 2019.
21. For example, my name in a text in TEI might be encoded as follows to designate which is my first name versus my last name and that I am the author: <persName type="author"><forename>AuthorFirstName</forename><surname>Author LastName</surname><persName>. Elements follow the pattern of an opening <element_name> element and a closing </element_name> element. Elements nest inside each other and @type is part of <persName> since the type applies to the whole name. Note that while the @ is never typed in actual TEI-XML code for attributes, it is the standard method for signaling that a word is an attribute.

```
<biblStruct type="book" xml:id="Bacon1603">
  <monogr>
    <title type="short">De arte chymiae scripta</title>
    <title level="m" ref="https://books.google.com/books?id=60tQSD8Dls8C"><hi rendition="#i">SANIORIS MEDICI</hi> |
      <hi rendition="#i">næ Magij/tri</hi> | D. ROGERI | BACONIS ANGLI, | DE ARTE CHYMIÆ | Icripta. | <hi rendition="#i">CVI
      ACCESSERVNT</hi> | <hi rendition="#i">opufcula alia ejufdem</hi> | <hi rendition="#i">Authoris.</hi> | [Ornament] | FRANCOFVRTI, |
      Typis Ioannis Saurij, Sumptibus Ioan- | nis Theobaldi Schönwetteri. | [Rule] | Anno M.
      DCIII.</title>
    <author><forename>Roger</forename><surname>Bacon</surname></author>
    <imprint>
      <pubPlace>Francofurti (Frankfurt am Main)</pubPlace>
      <publisher>Joannes Theobaldus Schönwetterus</publisher>
      <date>1603</date>
      <respStmt>
        <resp>Printer</resp>
        <persName>Joannes Saurius</persName>
      </respStmt>
    </imprint>
  </monogr>
  <note>[H110] Bacon, Roger. De arte chymiæ scripta. Cui accesserunt opuscula alia eiusdem
    authoris.  12°, Francofurti, 1603.  (Notes and page references by Newton relating to
    other alchemical works on fly-leaf and pp.43-4.) Tr/NQ.16.120    Metadata from Othmer
    Library, CHF  </note>
  <note>USTC/2039594</note>
  <note type="color"/>
</biblStruct>
```

Figure 2. Entry in bibliography for Bacon1603.

entry was contained within a <biblStruct> element. Further elements like <title> or <author> structured the pieces of bibliographic metadata. Most importantly, each source's entry had a unique identifier (using @xml:id) allowing for unequivocal reference to the source in the manuscripts themselves.[22] This is visible in Figure 2, which shows the entry for a 1603 edition of Roger Bacon's *De arte chymiae scripta*.[23]

Newton's in-text citations were encoded with the TEI element <bibl> and pointed to the correct source in the bibliography using a @corresp attribute.[24] This is similar to how in-text citations in an academic article may be separated from the main text using parentheses and the author's last name and other information points to a unique source in a bibliography. The passage at the beginning of this paper would be encoded as follows:

> Nam Lapidis ignis interior partim innatus partim more philosopico additus est: uniuntur quippe illi duo et introrsum coeunt quia homogenei sunt. **<bibl corresp="CHYM000001.xml#Despagnet1642">**ib. p. 72.**</bibl>**[25]

22. See TEI Consortium 2023a and TEI Consortium 2023e for more information about <biblStruct> and @xml:id.
23. All the bibliographic information is contained within the <biblStruct> and further structured with other elements. The unique identifier (@xml:id) is "Bacon1603" found in the opening <biblStruct> element.
24. See TEI Consortium 2023b and TEI Consortium 2023d for further documentation about <bibl> and @corresp.
25. The word "philosopico" would also be encoded using <sic> and <corr> elements as <choice><sic>philosopico</sic><corr>philosophico</corr></choice> to indicate Newton's mistaken spelling (<sic>) and the editors' correction (<corr>).

This is a form of descriptive markup because it is designating (describing) "ib. p. 72" as a citation via the <bibl> and stating that the citation refers to the source identified as "Despagnet1642" (TEI Consortium n.d-a). The <bibl> sets "ib. p. 72" off from the rest of the text, while the link (@corresp) points to the desired entry (Despagnet1642) in our bibliography.[26]

From a technical standpoint, this initial system is similar to our current system. We still have a bibliography file, and individual citations are encoded with a <bibl>. Almost 10,000 citations in sixty-five manuscripts were encoded under the older system, and once a manuscript was fully encoded, the publication date of the latest print source cited acted as the TPQ. For manuscripts like the successive drafts of the Index Chemicus, a personal alchemical reference guide created by Newton, this system is fairly successful because most citations have page numbers, and they can be traced to one and only one edition. Newton's biographer Richard Westfall had estimated that the initial drafts of the Index Chemicus were completed in the late 1670s and early 1680s and that the final draft, Cambridge, King's College Library, Keynes MS. 30/1, was finished in 1690 (Allen 2019, 73, 76). Meagan Allen used data from our older encoding of the bibliography and manuscripts to push the TPQ of all five drafts of the Index Chemicus to at least 1687 and to 1691 for the final draft (2019, 77).

Under the initial system, however, it is impossible to accomplish all three goals stated earlier: 1) accurate estimation of TPQ (dating), 2) analysis of Newton's alchemical study in terms of authors and works, and 3) provision of information to readers about Newton's sources. This is because the old system only works for "complete" citations with page numbers, and those page numbers must match only one edition or issue of the work Newton is citing.[27]

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26. More specifically, "CHYM000001.xml#Despagnet1642" attached to @corresp indicates that this citation should be connected to the bibliographic entry (<biblStruct>) with the @xml:id "Despagnet1642" in a file called CHYM000001.xml (the bibliography).

27. My and the project's definition of edition and issue match that described in Philip Gaskell's *A New Introduction to Descriptive Bibliography*. An edition is "all copies of a book printed at any time (or times) from substantially the same setting of type, and includes all the various impressions, issues, and states which may have derived from that setting" ([1972] 1995, 313). A reissue is a planned unit of publishing separated from another unit in time but it "must differ in some typographical way from copies of the edition first put on the market, yet be composed largely of sheets deriving from the original setting" ([1972] 1995, 315). Within the alchemical texts Newton uses, editions are often re-issued with a new title page with a new date which poses significant problems for dating. For example, the *Chymica vannus*

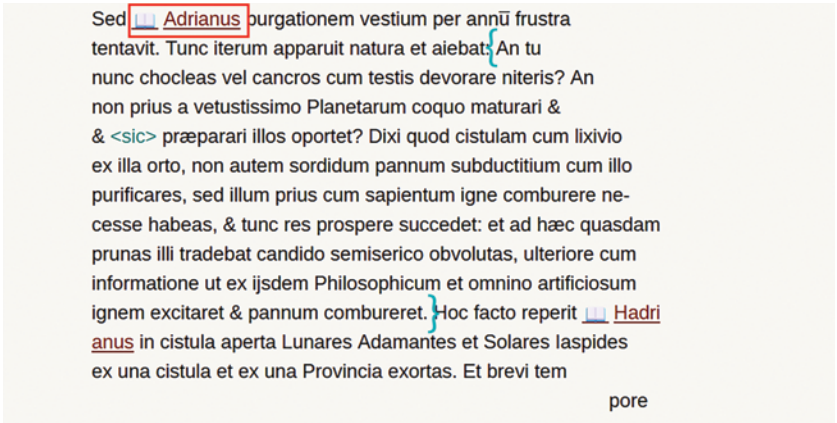

Sed Adrianus purgationem vestium per annū frustra
tentavit. Tunc iterum apparuit natura et aiebat: An tu
nunc chocleas vel cancros cum testis devorare niteris? An
non prius a vetustissimo Planetarum coquo maturari &
& <sic> præparari illos oportet? Dixi quod cistulam cum lixivio
ex illa orto, non autem sordidum pannum subductitium cum illo
purificares, sed illum prius cum sapientum igne comburere ne-
cesse habeas, & tunc res prospere succedet: et ad hæc quasdam
prunas illi tradebat candido semiserico obvolutas, ulteriore cum
informatione ut ex ijsdem Philosophicum et omnino artificiosum
ignem excitaret & pannum combureret. Hoc facto reperit Hadri
anus in cistula aperta Lunares Adamantes et Solares Iaspides
ex una cistula et ex una Provincia exortas. Et brevi tem
pore

Figure 3. Jerusalem, National Library of Israel, Yahuda Var. 1/Newton Papers 38, charta 3*r* (Chymistry of Isaac Newton transcription).

A significant number of Newton's citations do not contain page numbers and/or do not match a single edition or issue, which presents a challenge for the initial encoding system. For example, as seen in Figure 3, in Jerusalem, National Library of Israel, Yahuda Var. 1/Newton Papers 38, Newton gives a very terse citation of "Adrianus" for a passage that he directly quotes from Adrianus von Mynsicht's *Aureum saeculum redivivum* (charta 3*r*). Not only does this citation not include a page number, but there are also two different editions published more than fifty years apart that contain this passage: *Musaeum hermeticum* (Frankfurt am Main: Lucas Jennisius, 1625) and *Musaeum hermeticum reformatum et amplificatum* (Frankfurt am Main: Hermannus à Sande, 1678).[28] If Newton had indicated p. 92, then it would be evidence for Newton using the 1625 edition (Figure 4), but if he had put p. 67, it would match the 1678 edition (Figure 5).

published in 1666 (Amstelodami: Apud Joannem Janssonium à Waesberge, & Elizeum Weyerstraet; see *Chymica vannus* 1666) was re-issued as *Chymiae aurifodina incomparabilis* in 1696 (Lugduni Batavorum: Sumptibus Autoris; see *Chymiae aurifodina* 1696). Page numbers in Newton's citations cannot distinguish between the two issues and therefore cannot contribute to dating since the sheets come from the same setting of type.

28. See Musaeum hermeticum 1625 and Musaeum Hermeticum reformatum 1678.

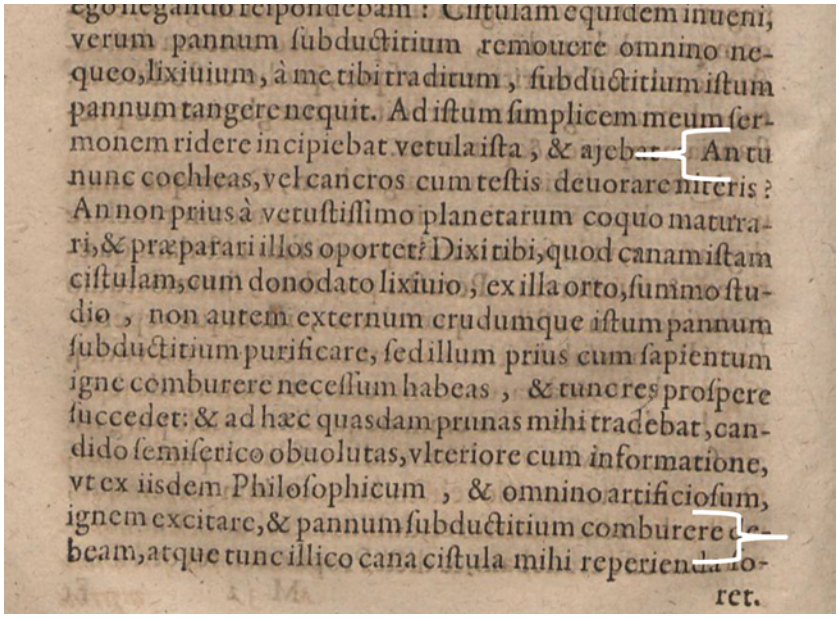

ego negando respondebam: Ciſtulam equidem inueni,
verum pannum ſubductitium remouere omnino ne-
queo, lixiuium, à me tibi traditum, ſubductitium iſtum
pannum tangere nequit. Ad iſtum ſimplicem meum ſer-
monem ridere incipiebat vetula iſta, & ajeba[illegible] An tu
nunc cochleas, vel cancros cum teſtis deuorare niteris?
An non prius à vetuſtiſſimo planetarum coquo matura-
ri, & præparari illos oportet? Dixi tibi, quod canam iſtam
ciſtulam, cum donodato lixiuio, ex illa orto, ſummo ſtu-
dio, non autem externum crudumque iſtum pannum
ſubductitium purificare, ſed illum prius cum ſapientum
igne comburere neceſſum habeas, & tunc res proſpere
ſuccedet: & ad hæc quasdam prunas mihi tradebat, can-
dido ſemiſerico obuolutas, vlteriore cum informatione,
vt ex iisdem Philoſophicum, & omnino artificioſum,
ignem excitare, & pannum ſubductitium comburere d[illegible]
beam, atque tunc illico cana ciſtula mihi reperienda fo-
ret.

Figure 4. The passage in question on p. 92 of the 1625 *Musaeum hermeticum* edition. Screenshot from digital copy of Staats- und Universitätsbibliothek Dresden.

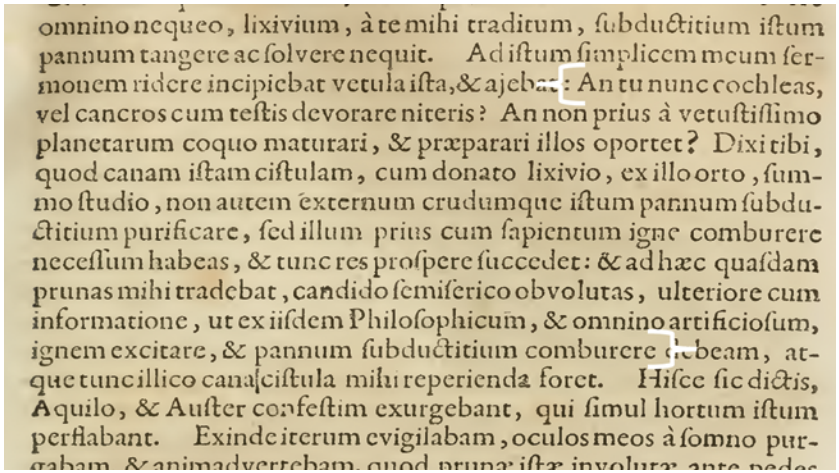

omnino nequeo, lixivium, à te mihi traditum, ſubductitium iſtum
pannum tangere ac ſolvere nequit. Ad iſtum ſimplicem meum ſer-
monem ridere incipiebat vetula iſta, & ajeba[illegible]: An tu nunc cochleas,
vel cancros cum teſtis devorare niteris? An non prius à vetuſtiſſimo
planetarum coquo maturari, & præparari illos oportet? Dixi tibi,
quod canam iſtam ciſtulam, cum donato lixivio, ex illo orto, ſum-
mo ſtudio, non autem externum crudumque iſtum pannum ſubdu-
ctitium purificare, ſed illum prius cum ſapientum igne comburere
neceſſum habeas, & tunc res proſpere ſuccedet: & ad hæc quaſdam
prunas mihi tradebat, candido ſemiſerico obvolutas, ulteriore cum
informatione, ut ex iiſdem Philoſophicum, & omnino artificioſum,
ignem excitare, & pannum ſubductitium comburere d[illegible]beam, at-
que tunc illico cana ciſtula mihi reperienda foret. Hiſce ſic dictis,
Aquilo, & Auſter confeſtim exurgebant, qui ſimul hortum iſtum
perflabant. Exinde iterum evigilabam, oculos meos à ſomno pur-
gabam, & animadvertebam, quod prunæ iſtæ involutæ ante pedes

Figure 5. The passage on p. 67 of the 1678 *Musaeum hermeticum reformatum et amplificatum* edition. Screenshot from Internet Archive copy contributed by Getty Research Institute.

If it were the 1678 edition and the latest published source in the manuscript, then this citation would provide a TPQ of 1678. Alternatively, if Newton used the 1625 edition, then this citation is not usable for dating at all because Newton was not even born until 1643. Even worse, Newton owned both editions (Harrison 1978, 197).[29]

Under the old system described above, there are two overall strategies for handling these citations that do not connect to a single edition or issue, neither of which accomplishes all three goals. On one hand, one could ignore all inconclusive citations and provide links to sources only for those citations that are definitively linked to one edition/issue. In other words, no source could be linked to the Adrianus citation or the earlier d'Espagnet citation. On the other hand, for all citations in which the work (but not a specific edition/issue) can be identified, one could provide links to all the potential sources for the citation or the most likely or convenient one. For the Adrianus citation, we might link to either the 1625 or 1678 editions, and for d'Espagnet to either of the 1642 editions.

In the first case, all citations linked to sources can be used for calculating the TPQ because the citations are correctly connected to specific editions/issues and therefore their dates of publication are known.[30] At the same time, thousands of citations are ignored which could be connected to works and authors. In thirty manuscripts (1,701 citations) encoded according to the updated system, we have identified the correct work in 90.8% of citations and the exact edition in 42.5%. If only citations with identifiable editions were encoded, no information would be provided about Newton's source for 48.3% of his citations. Encoding in this manner would erase valuable information about authors and works Newton consulted from our analysis of his alchemical studies and provide less information in the digital editions. None of the citations to d'Espagnet's works — such as the one at the beginning of this essay — would be recorded because they cannot be traced to a specific edition, and thus we would have no convenient way to calculate that Newton referenced d'Espagnet in at least 223 citations in eighteen manuscripts.

In the second case, by ignoring the importance of indicating that a citation refers to a specific edition, we cannot perform a rigorous analysis of citations to determine the TPQ of any manuscript. Without the ability

29. Both copies survive at Trinity College Cambridge's library under shelfmark NQ.16.115 (1625 edition) and NQ.16.148 (1678 edition).

30. Citations linked to sources are all those citations with a @corresp with a value pointing to the bibliography in their <bibl>.

to specify which citations are traceable to an exact edition, it is impossible to tell whether the source with the latest publication date cited in the manuscript is the only edition that could possibly be referenced by the citation. We might provide more information about Newton's sources to the reader with this strategy, but we cannot provide as precise information since, for imperfect citations, we would have to choose one edition from among many plausible ones. There is also no mechanism for stating that there are multiple plausible editions and why the citation is linked to one in particular.

Current encoding framework

The new system needed to solve the problems arising from the initial system's limitations and address the three goals of dating manuscripts, keeping track of the authors and works Newton used, and providing more information to readers. This was accomplished by establishing four levels of certainty which indicate our confidence that a source linked to a citation was actually that used/referenced by Newton and adding an optional note to citations to explain bibliographical complexities when necessary. These two pieces allow us to consistently encode citations despite variances in Newton's citational practice and the complications of early modern print. By assigning levels of certainty to citations, we can distinguish between those citations in which we have full certainty that Newton used a particular source (and thus use them for calculating TPQ) and those where we have less than full certainty. The bibliographic note provides the space to explain the relationship between a citation and its source to readers. In this section, I will describe the certainty framework, bibliographic notes, and their application in more detail, as well as other remaining challenges in implementing the current encoding system, such as dealing with Newton's inconsistent habits in writing citations and taking into account Newton's linguistic abilities when making certainty judgements.

The parts of a citation

Like the initial encoding system, the current encoding system has a bibliography and citations referencing it. No real changes were made to the bibliography, but with the addition of markers of certainty and bibliographic notes, in-text citations in the current encoding system consist

of four parts: the citation itself, a pointer to the source, a marker of certainty, and a bibliographic note.[31] Depending on the situation, a citation may have one, some, or all of these parts. As with the older encoding system, the text of the citation is denoted using the <bibl> element so that it can be distinguished from the rest of the text.[32] The citation consists of any words that identify the source (title, author name, etc.) and where the cited material is (page number, section number, section name).[33] The pointer to the source (@corresp) also performs the same function as in the previous system: it connects the citation to the proper entry for the cited source in our bibliography. The certainty marker (@cert) marks the level of certainty (or confidence) that the source indicated by the pointer was the source used by Newton. If it is present, it has one of two values: "unknown" or "high".[34] The combination of the pointer (@corresp) and the certainty marker (@cert) allows for encoding citations with four levels of certainty (to be discussed in a moment). Finally, the note (<note>) is placed inside the <bibl>.[35] Not all citations need notes, but they inform readers where the information referenced by the citation is located in the source, provide bibliographic details, and/or explain why a citation is connected to a particular source.

A four-level framework for certainty

Whether a citation needs a pointer to a source (@corresp), a certainty marker (@cert), and/or a note (<note>) depends on whether we can determine the exact source Newton used, whether only the work can be

31. In our TEI encoding, these are encoded using <bibl>, @corresp, @cert, and <note type="biblio">.
32. The exception are citations that Newton copies out of sources. These are not original citations by Newton, so they cannot be used for dating under any circumstances. Editorial annotations (a different type of note used in the *Chymistry* project) are sometimes added near these citations to indicate to the reader they are not original citations by Newton and therefore not encoded with sources.
33. The <bibl> does not enclose quoted or paraphrased material preceding or following the citation.
34. For example: <bibl corresp="source_id" cert="high"> or <bibl corresp="source_id" cert="unknown">. For more about @cert, see TEI Consortium 2023c.
35. The <note> has the attribute @type with the value "biblio" to distinguish it from other types of <note> elements used for encoding Newton's manuscripts. For more about <note>, see TEI Consortium 2023f.

determined, or whether we can even assign a work to the citation. In other words, the inclusion of these other three components depends on our "certainty" that Newton meant to indicate a particular source or work in a given citation. Using different combinations of the pointer (@corresp) and certainty marker (@cert), we express four different levels of certainty in our framework: "verified", "high likelihood", "unknown likelihood", and "ambiguous" as seen in Table 1. These broadly correspond to the following interpretations about the relationship between a citation and its source: the unique source is known (verified); the work is known and likely the unique source (high likelihood); the work is known, but there are multiple plausible sources (unknown likelihood); and the work is unknown and/or no plausible sources are known (ambiguous).[36]

Table 1. Certainty framework for citations.[37]

Certainty	**@corresp**	**@cert**	**Meaning**	**Application to *Chymistry***
Verified	source @xml:id	No value	Unique source known	A citation is deemed verified when Newton has indicated page numbers in a citation and those page numbers can connect the citation to one and only one edition or issue of a work or compilation.
High likelihood	source @xml:id	"high"	Work known, very likely to be a particular unique source	A citation is assigned high likelihood when the editor has confidence that Newton is citing a particular edition

(*Continued*)

36. By "work", we mean either compilations or book-length single works since many alchemical texts are short and appear in multiple compilatory works.
37. It should be noted that while there are four levels of certainty, there are only two values for the certainty marker. It would also be valid to make @cert required for every citation and have the potential values be "verified", "high", "unknown", and "ambiguous". However, we felt it was more efficient to have only two values since verified and ambiguous citations can be distinguished from each other by the presence or absence of @corresp. Additionally, it could be argued that verified and ambiguous citations are similar in that there is full certainty in our judgement, and therefore they do not need a certainty marker: we are sure of our selected source in verified citations and we are sure that we cannot identify any reasonable source for ambiguous citations.

Table 1. Continued.

Certainty	@corresp	@cert	Meaning	Application to *Chymistry*
				or issue of a work because of contextual factors like word choice or the age of the manuscript, but the editor cannot definitively ascribe the citation to that particular edition or issue because Newton has failed to indicate page numbers.
Unknown likelihood	source @ xml:id	"unknown"	Work known, multiple plausible sources	A citation is assigned unknown likelihood when the editor has confidence in the identity of the work Newton is citing but is uncertain about the edition or issue.
Ambiguous	No value	No value	Work unknown and/or source unknown	A citation is deemed ambiguous when it cannot be sufficiently assigned to a particular work, much less an edition or issue.

When applying these levels of certainty to the *Chymistry* project, the usual evidence for determining the certainty is whether there are page numbers in the citation that can narrow the potential sources to just one edition or issue of a work by process of elimination (i.e., only one edition or issue has the cited material on the page indicated). This is because most of what Newton cites are print sources, so pagination (or lack thereof) can help determine whether it is possible to identify a unique source, only a unique work, or neither. However, this is merely the standard of proof that works well for the *Chymistry* project. Other projects seeking to use this system of certainty need not use pagination if that does not make sense, such as if cited sources are primarily foliated printed and manuscript sources. The key is to determine what evidence in a particular situation is sufficient to make the certainty judgement: that the citation can only refer to one source and no other as in verified citations, that it could refer to many but very likely one source as in high likelihood citations, that it could refer to several equally likely sources

<bibl corresp="CHYM000001.xml#Zetzner1660"><persName>Astanus maximus</persName> apud Micrerim in Th. Ch. v. 5 p 92</bibl>.

Figure 6. TEI encoding of verified citation for Cambridge, King's College Library, Keynes MS. 57, charta 2*r*.

as in unknown likelihood citations, or that there is no plausible source at all as in ambiguous citations.

To understand the application of these certainty levels better and how they are encoded in TEI, it is helpful to discuss some real examples taken from the *Chymistry* project. Beginning with the highest level of certainty, verified citations are the "perfect" citations; they match just one edition or issue of a work or compilation via a page number. These citations connect to a unique source and can therefore be used for calculating the TPQ of the manuscript. As such, they generally only contain two components: the <bibl> to mark the text of the citation and the pointer (@corresp) to mark the unique source. Figure 6 above shows a citation to volume five of the *Theatrum chemicum* (Argentorati: Sumptibus Heredum Eberh. Zetzneri, 1660).[38] The text of the citation ("Astanus maximus apud Micerim in Th. Ch. V. 5 p 92") is contained by the <bibl>, and the point (@corresp) contains the unique ID for volume 5 of the *Theatrum chemicum*: "Zetzner1660".

A bibliographic note giving information about the source is not usually necessary for verified citations because each citation in the future *Chymistry* site will have an icon next to it which users can click to see a formatted citation for the identified source and a link to a digital facsimile of the source. When there are notes, such as if Newton's cited passage is on more pages than those indicated by the citation, the notes will appear with the formatted citation. Figure 7 shows how these formatted citations and links will look, alongside a note stating that the material cited is on pages twenty-six and twenty-seven, not just twenty-seven as Newton indicates.[39]

38. See *Theatrum chemicum* 1660.
39. The citation in Figure 7 would be encoded in TEI as follows: <bibl corresp="Artis1610_2">ib p 27.<note type="biblio" resp="alewinga">The information referenced is on pp. 26–27</note></bibl>. "Artis1610_2" is the ID for volume 2 of the 1610 *Artis auriferae*.

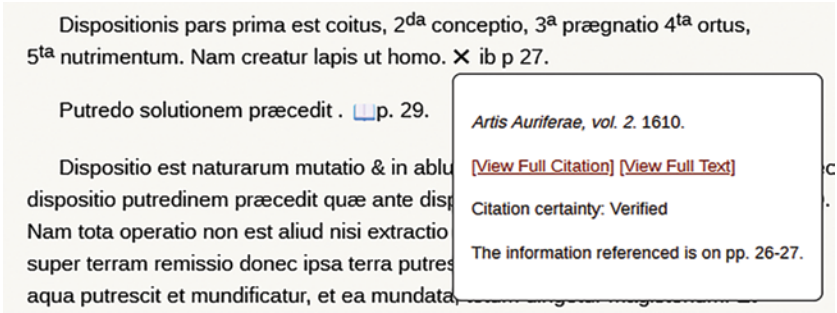


Figure 7. Example bibliographic pop-up from Cambridge, King's College Library, Keynes MS. 12, charta 6*r* in *Chymistry of Isaac Newton* transcription.[40]

Moving down to the next level of certainty, high likelihood citations are those citations where the work is known, and there is technically more than one plausible source, but one source is much more likely to be the one referenced. Applying this to *Chymistry*, high likelihood citations occur when there are two or more plausible editions or issues (and occasionally manuscript sources) that Newton could be citing, but because of context (e.g., Newton's word choice, non-citational evidence regarding the age of the manuscript) one edition is much more likely. The citation therefore contains both a pointer (@corresp) to the source believed to most likely be correct and a certainty marker (@cert) with the value "high". A bibliographic note is required to explain the source choice so that readers may judge the reasoning for themselves.[41] Figure 8 shows a high likelihood citation to Edmund Dickinson's *Epistola* (Oxoniae: E Theatro Sheldoniano, 1686). Here, the ID of the source ("Dickinson1686") is in the pointer (@corresp), the certainty marker is included with the value "high", and the bibliographic note explains that while the citation lacks a page number and technically both the 1686 and 1687 editions are plausible, other citations to Dickinson's work in the manuscript can be definitively traced through page numbers to the 1686 edition. It seems unlikely that Newton switched to a different edition for just one citation in the same

40. NB: While the re-encoded manuscripts already contain the encoding necessary to support these pop-ups, the updated *Chymistry of Isaac Newton* website that will have the pop-up capability has not been launched as of the time of writing. However, the transcriptions of all manuscripts used in this essay are available on the existing live site (www.chymistry.org).
41. There is also a required @resp on the <note type="biblio"> containing an ID for the note author. This allows us to track who wrote the note for what citation.

```
<bibl corresp="CHYM000001.xml#Dickinson1686" cert="high"><persName>Mundanus</persName><note
type="biblio" resp="alewinga">Newton is referencing Edmund Dickinson's <hi rend="i">Epistola...ad Theodorum
Mundanum</hi>. See p. 162 of the 1686 edition (Oxoniae: E Theatro Sheldoniano). While there is another edition of this
work in approximately 1687 (see Wing 2nd ed. 1994, D1384), where the same information appears on p. 130, this citation is
rated as "high likelihood" to be the 1686 edition because there are 4 paginated citations in this manuscript traceable to that
edition, and Newton's copy survives at Trinity College Camridge (shelfmark NQ.16.89).</note></bibl>
```

Figure 8. High likelihood citation from TEI encoding of Cambridge, King's College Library, Keynes MS. 57, charta 9*r*.

manuscript, so there is high likelihood that the 1686 edition is the correct source for this citation too. As in Figure 7, the pop-up will display this explanatory note to readers.

Interestingly, the "Adrianus" example discussed earlier in conjunction with Figures 3–5 is also a "high likelihood" citation. Newton has a series of six citations to Adrianus von Mynsicht's *Aureum saeculum redivivum* in a row on chartae 3*r*–3*v* of Jerusalem, National Library of Israel, Yahuda Var. 1/ Newton Papers 38, and he very closely copies the content of Mynsicht's work. In one instance on charta 3*r*, Newton uses the phase "Lunares Adamantes et Solares Jaspides". This phrase matches page 93 of the 1625 *Musaeum hermeticum*, but the 1678 *Musaeum hermeticum Reformatum et Amplificatum* has "Lunares adamantes, et solares *rubinos*" (*Musaeum Hermeticum* 1678, 68 [mispaginated as 58; emphasis added]). Given that Newton was copying so closely, we felt this change in wording between the two editions was sufficient evidence to assign "high likelihood" certainty to all six citations referring to Mynsicht's *Aureum saeculum redivivum* as being the 1625 edition.

Our certainty for the specific source of many citations is frustratingly "unknown likelihood", meaning that there are two or more sources to which the citation could be referring. For the *Chymistry* project, this means that there is more than one plausible edition or issue and occasionally manuscript. In order to provide the reader with information about what source Newton possibly used, we choose one edition/issue over the other for either a specific reason (e.g., Newton owned it, the digitized copy is better) or just arbitrarily. Either way, a bibliographic note is obligatory in order to explain that there are multiple plausible sources, give basic bibliographic information for at least two sources, state where the material cited appears in both sources, and outline the reason we have chosen to link to a particular source. The pointer contains the ID of the chosen source, and the certainty marker has the value "unknown".[42] For example, Figure 9 shows an encoded citation found on

42. In other words, the @corresp contains the value of the source we prefer and @cert equals "unknown".

```
2437                <bibl corresp="CHYM000001.xml#Boyle1660" cert="unknown"><name><choice><orig>M<hi
2437 rend="super">r</hi></orig><reg>Mr.</reg></choice> Boyles</name> Experiments,
2437 <choice><abbr>Exper</abbr><expan>Experiment</expan></choice> 43 <note type="biblio" resp="alewinga">Newton is
2437 referencing Robert Boyle's <hi rend="i">New Experiments Physico-mechanical</hi>. Newton's source text cannot be
2437 confirmed, but see pp. 388–393 in <hi rend="i">New Experiments Physico-mechanicall</hi> (Oxford: H. Hall for Tho.
2437 Robinson, 1660) or pp. 202–204 in <hi rend="i">New experiments physico-mechanical</hi> (Oxford: H. Hall for Tho.
2437 Robinson, 1662). We have linked to the 1660 edition since Newton's copy survives at Trinity College Cambridge
2437 (shelfmark NQ.10.69.).</note></bibl>.
```

Figure 9. Unknown likelihood citation from TEI encoding of Cambridge, Cambridge University Library, Portsmouth Collection, Add. MS. 3975, charta 24*r*.

charta 24*r* of Cambridge, Cambridge University Library, Portsmouth Collection, Add. MS. 3975, which has been assigned "unknown likelihood" and linked to the 1660 edition of Robert Boyle's *New Experiments Physico-mechanical* (Oxford: H. Hall for Tho. Robinson).[43] As the bibliographic note states, there are at least two plausible editions: the 1660 edition and another 1662 edition. Since the text of Newton's citation merely notes the experiment number (forty-three) instead of the page number, it is impossible to tell which edition Newton used. It was decided that the pointer should link to the 1660 edition since Newton owned that edition and his copy still survives at Trinity College Cambridge. Therefore, the citation is encoded with a <bibl> to indicate it is a citation, the pointer has the value of the ID for the 1660 edition in the bibliography, the certainty marker's value is "unknown", and the bibliographic note describes both editions, where the information occurs, and why the 1660 edition was chosen.

Finally, ambiguous citations are those where there is not enough confidence to assign even a work much less a specific source. This often occurs when Newton simply cites an author's name, but it also happens with paginated citations when the material on the stated page does not seem to be an obvious match for what Newton has written down. It could be that Newton made a mistake and wrote down the wrong page, title, or author, or we may not understand the association that Newton made with the passage. Either way, we prefer to be cautious rather than advance a theory with little evidence about the connection since Newton does make mistakes on occasion. These ambiguous citations are still encoded with <bibl> because they are still citations, but they contain neither pointers to sources nor certainty markers since there is no source to be linked or about which to be certain. A short bibliographic note is still necessary, however, to explain for the reader that the content on the page is not an obvious match for what Newton has written or that the citation cannot be connected to a specific work, as shown in the two citations in Figure 10. Neither the citation "Manna" nor "Turba et alij

43. See Boyle 1660.

```
956                    volatilium ut 1 ad 3 vel 1 ad 3 1/2 (<bibl>Manna<note type="biblio" resp="alewinga">This citation
957 cannot be connected to a specific work.</note></bibl>, <bibl>Turba et <choice><orig>alij</orig><reg>alii</reg></choice>
958 passim<note type="biblio" resp="alewinga">This citation cannot be connected to a specific work.</note></bibl>) <seg hand="
959 #unknown">8</seg><lb/>
```

Figure 10. Ambiguous citation in TEI encoding of Cambridge, King's College Library, Keynes MS. 57, charta 8*r*.

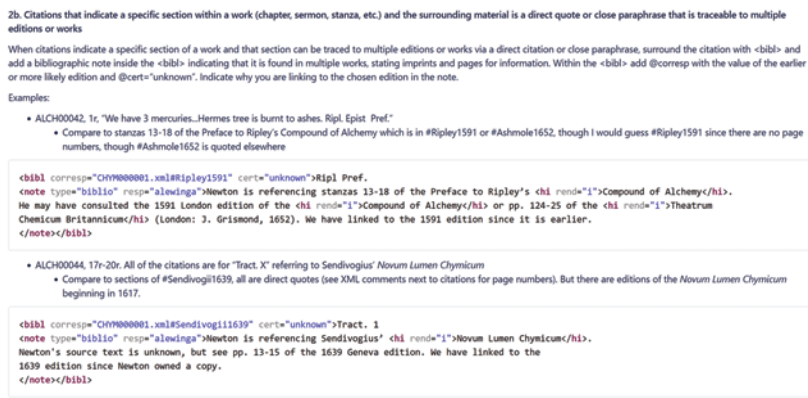
passim" and the content near them could be traced to a work and plausible sources, so they could not reach the threshold for "unknown likelihood" and therefore are classified as ambiguous citations.

Challenges in assigning certainty

These four levels of certainty have worked extremely well for the *Chymistry* project, but deciding which level of certainty is appropriate in regard to a particular citation can have its challenges. In the first place, Newton's habits in referencing material vary — both in terms of the citation and the material referenced — and affect what level of certainty can be assigned. As demonstrated by the earlier Adrianus von Mynsicht and Robert Boyle examples, not all citations have page numbers. Further, Newton sometimes heavily paraphrases instead of quoting. For multiple encoders to encode these irregular citations consistently, it was necessary to create rules stating the maximum level of certainty given the number of plausible sources and the form of the citation. Figure 11 shows the citation forms are divided by citations that use page numbers, citations that use section indicators (numerical or textual), and citations without a page number. It has also been necessary to determine procedures for handling citations in the manuscript that are not original to Newton (e.g., citations he copies out of a print source) and citations to Newton's own manuscripts.

This taxonomy of Newton's citation forms allows individual encoders to assess each citation and follow the correct course of action. For example, Figure 12 below shows the instructions for case 2b, citations with a section indicator that can be traced to multiple editions. Encoders are directed to mark the citation as having a certainty of "unknown likelihood" since the work is known but there are multiple plausible editions and to link to one of the plausible editions using a pointer (the @corresp). The note should identify where the information is in the plausible editions mentioned and state why one edition has been linked to instead of the other(s).

Figure 11. Table of contents to the *Chymistry of Isaac Newton* citation encoding guidelines.



2b. Citations that indicate a specific section within a work (chapter, sermon, stanza, etc.) and the surrounding material is a direct quote or close paraphrase that is traceable to multiple editions or works

When citations indicate a specific section of a work and that section can be traced to multiple editions or works via a direct citation or close paraphrase, surround the citation with <bibl> and add a bibliographic note inside the <bibl> indicating that it is found in multiple works, stating imprints and pages for information. Within the <bibl> add @corresp with the value of the earlier or more likely edition and @cert="unknown". Indicate why you are linking to the chosen edition in the note.

Examples:

- ALCH00042, 1r, "We have 3 mercuries...Hermes tree is burnt to ashes. Ripl. Epist Pref."
  - Compare to stanzas 13-18 of the Preface to Ripley's Compound of Alchemy which is in #Ripley1591 or #Ashmole1652, though I would guess #Ripley1591 since there are no page numbers, though #Ashmole1652 is quoted elsewhere

```
<bibl corresp="CHYM000001.xml#Ripley1591" cert="unknown">Ripl Pref.
<note type="biblio" resp="alewinga">Newton is referencing stanzas 13-18 of the Preface to Ripley's <hi rend="i">Compound of Alchemy</hi>.
He may have consulted the 1591 London edition of the <hi rend="i">Compound of Alchemy</hi> or pp. 124-25 of the <hi rend="i">Theatrum
Chemicum Britannicum</hi> (London: J. Grismond, 1652). We have linked to the 1591 edition since it is earlier.
</note></bibl>
```

- ALCH00044, 17r-20r. All of the citations are for "Tract. X" referring to Sendivogius' *Novum Lumen Chymicum*
  - Compare to sections of #Sendivogii1639, all are direct quotes (see XML comments next to citations for page numbers). But there are editions of the *Novum Lumen Chymicum* beginning in 1617.

```
<bibl corresp="CHYM000001.xml#Sendivogii1639" cert="unknown">Tract. 1
<note type="biblio" resp="alewinga">Newton is referencing Sendivogius' <hi rend="i">Novum Lumen Chymicum</hi>.
Newton's source text is unknown, but see pp. 13-15 of the 1639 Geneva edition. We have linked to the
1639 edition since Newton owned a copy.
</note></bibl>
```

Figure 12. Citation encoding guidelines for section 2b.

A second factor arises from Newton's linguistic abilities. Newton was fluent in both English and Latin, and he had some abilities with French, likely due to his collaboration with the French chymist Nicolas Fatio de Duillier (Newman 2019, 370). Newton's ability to switch between languages means that the language of the material cited in Newton's manuscript may not match that of the original source. For example, George Starkey's *Introitus apertus* (Amstelodami: Apud Joannem Janssonium a Waesberge & Viduam ac Haeredes Elizei Weyerstraet, 1667) was originally published in Latin and then later translated and revised into the English *Secrets Reveal'd* (London: W. Godbid for William Cooper, 1669).[44] One might think a citation using a form of "Introitus apertus" would automatically mean Newton was referencing the Latin version, and a citation using a form of "Secrets Revealed" indicates the English one, but this is not the case. "Intr. apert p 6, 20" and "Introit apert p. 6, 13, 16" in Cambridge, King's College Library, Keynes MS. 57 are both connected as verified citations to *Secrets Reveal'd* (charta 9*v*). In other cases, Newton's linguistic abilities mean a source cannot be tracked down. Cambridge, King's College Library, Keynes MS. 63 contains English translations of several texts ostensibly attributed to Basilius Valentinus. These texts did not originally appear until 1602, when they were published in German in *Ein kurtzer summarischer Tractat Fratris Basilij Valentini* (Leipzig: Jacob Apel), and they often have been ascribed to Johann Thoelde, who edited the book (Principe 2019, 551–53). Other German editions of these texts followed, but no known, surviving edition exists of them in English, French, or Latin, so we have theorized that Newton accessed a manuscript that had an English translation of the copied texts. However, without knowing the specific manuscript, all citations to these texts in Cambridge, King's College Library, Keynes MS. 63 are rated as ambiguous. The work is known, but there are no known plausible sources because the German sources cannot be the direct source of Newton's excerpts.[45]

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44. See Philaletha 1667 and Philaletha 1669. Eirenaeus Philaletha, Eirenaeus Philalethes, and other variants are frequent pseudonyms of Starkey.
45. Newton's citations in Cambridge, King's College Library, Keynes MS. 63 are interesting because they specify where the texts occur in relation to other texts within his source, such as "Verses at the end of B. Valentine's mystery of the Microcosm" (charta 1*r*). The verses in question are a work eventually known as *De macrocosmo*, and they do indeed occur after *De microcosmo* in *Ein kurtzer summarischer* and other German texts. See *Ein kurtzer summarischer* 1602.

There are other potential challenges that we have not encountered yet, such as the possibility of intermediary citations, meaning that Newton's true direct source (i.e., what he consulted at the moment of making the citation) is obscured because he copies content and a citation to another work from that true direct source which makes that citation seem like the true source.[46] However, the certainty framework, bibliographic notes, and consistent encoding guidelines make the current encoding system robust enough to handle almost anything that arises in Newton's manuscripts. Bibliographical complications of works, editions, issues, and line-by-line reprints in early modern print can be recorded and taken into account when assigning sources. Citations with page numbers, section numbers, or even just titles and author names can contribute to our knowledge of Newton's sources. This was not possible with the initial encoding system because it was impossible to indicate the certainty that Newton used a particular source. With the current encoding system, all citations in some manner provide valuable evidence of Newton's alchemical work and can be used judiciously in analyses, either on a micro-level or a macro-level, as some of the preliminary analyses in the next section will demonstrate.

46. For example, Newton hypothetically could copy "For as one Planet is more ponderous/Then is another and flower, in his course Norton p. 84", and one would think the source is *Theatrum Chemicum Britannicum* (London: J. Grismond for Nathaniel Brooke, 1652) because that text occurs on page 84 (See Ashmole 1652, 84). However, perhaps another alchemical text also excerpts that phrase along with the citation, and Newton really copied from this second text, not the *Theatrum Chemicum Britannicum*. We have yet to come across a clear-cut example of this. The closest might be a reference to Artephius' *Liber secretus* in Cambridge, King's College Library, Keynes MS. 66: "Our Aqua lunaris or crude white sulphur or double distilled Vinegar or Vinegar of the mountains (as Artephius calls it)" (charta 3*v*). Potential sources include either the French or Latin texts in *Trois traitez de la philosophie naturelle* (Paris: Guileaume Marette, 1612; see Arnaud 1612) or any of the other editions or issues dated 1612, 1659, and 1682, in addition to Newton's manuscript Cambridge, King's College Library, Keynes MS. 14, charta 2*v* which is a copy of the English translation of Artephius printed in 1624 as part of *Nicholas Flammel, His Exposition of the Hieroglyphicall Figures* (London: T.S. for Thomas Wakley; see Orandus 1624). In the end, we linked to the 1612 *Trois traitez* because it was the earliest dateable source and assigned "unknown likelihood" for certainty.

Results of the new encoding framework

The new encoding framework has been in use for almost four years now, and 1,919 citations in forty-seven manuscripts have been re-encoded from the old system or encoded for the first time according to the new framework as of February 2024.[47] With the inclusion of citation certainty and explanatory bibliographic notes where necessary according to the new framework, we have begun to fulfill all three goals in the citation work: providing precise and accurate information on the sources Newton used, dating or ordering his manuscripts, and analyzing his use of alchemical sources. This final section will present preliminary results in all three areas.

Informing users

The act of informing users — whether they are scholars, lay readers, or even members of the project — about the sources Newton used has been greatly facilitated by adding bibliographic notes to citations. This has allowed us to provide information to help users locate the passage in the source text should they choose to follow the link to the digitized copy of the source, information about where Newton's copy is now (if known), and information about how the citation was traced to a particular source and our certainty. Three examples demonstrate varying levels of detail in notes. Figure 13 shows a note connected to a citation in Cambridge, Cambridge University Library, Portsmouth Collection, Add. MS. 3975 that reads "Ibid." (charta 12*v*), referring to Robert Boyle's *Essays of the Strange*

Boyle, Robert. *Essays of the Strange Subtilty, Determinate nature, Great Efficacy of Effluviums*. Moses Pitt, 1673.

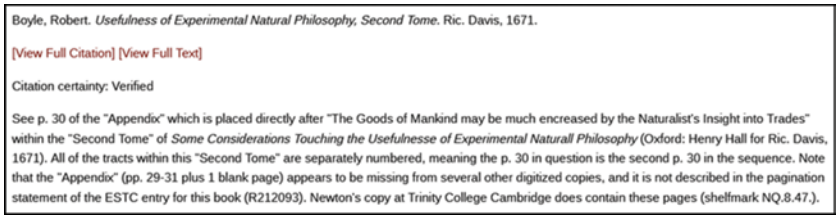
[View Full Citation] [View Full Text]

Citation certainty: Verified

Essays of the Strange Subtilty, Determinate nature, [and] Great Efficacy of Effluviums contains multiple series of paginations. See pp. 25-26 within "Of the Determinate Nature of Effluviums." The linked digital facsimile is Newton's own copy held at the University of Wisconsin-Madison (call number Duveen D 267).

Figure 13. Bibliographic note by author for verified citation in Cambridge, Cambridge University Library, Portsmouth Collection, Add. MS. 3975, charta 12*v*.

47. Citation encoders for the new system are as follows: Alexandra Wingate, Madeline Keyser, Finch Collins, Cassidy Pollack, and Seth Cope.


Boyle, Robert. *Usefulness of Experimental Natural Philosophy, Second Tome.* Ric. Davis, 1671.

[View Full Citation] [View Full Text]

Citation certainty: Verified

See p. 30 of the "Appendix" which is placed directly after "The Goods of Mankind may be much encreased by the Naturalist's Insight into Trades" within the "Second Tome" of *Some Considerations Touching the Usefulnesse of Experimental Naturall Philosophy* (Oxford: Henry Hall for Ric. Davis, 1671). All of the tracts within this "Second Tome" are separately numbered, meaning the p. 30 in question is the second p. 30 in the sequence. Note that the "Appendix" (pp. 29-31 plus 1 blank page) appears to be missing from several other digitized copies, and it is not described in the pagination statement of the ESTC entry for this book (R212093). Newton's copy at Trinity College Cambridge does contain these pages (shelfmark NQ.8.47.).

Figure 14. Bibliographic note by author for verified citation in Cambridge, Cambridge University Library, Portsmouth Collection, Add. MS. 3975, charta 49*r*.

Subtilty, Determinate nature, Great Efficacy of Effluviums (1673). Through the note, we have indicated the section and pages in which the content cited appears and noted that the linked copy is in fact Newton's copy.[48]

Figure 14 shows a slightly more complex note, again part of a citation to Boyle (though a different text). As with Figure 13, there are some complexities in pagination to explain in order to direct the reader to the right place. We also include more complex bibliographic information, noting that most other digitized copies do not even have the appendix in question, and it is not present in a standard bibliographic description.[49]

Figure 15 shows the maximum level of detail that a bibliographic note may acquire. Here, the bibliographic note explains why a particular edition is a plausible source for the citation "Plin. L. 32. C. 4." (Cambridge, King's College Library, Keynes MS. 30/1, charta 32*r*). The note distills that research and presents our reasoning for choosing the 1587 Lyon *Historiae mundi* of Pliny for readers. Newton's library does not list a complete Latin edition of Pliny's work of natural history, so many different editions could have plausibly been used by Newton (Harrison 1978). The note constitutes an extensive amount of research combining evidence from multiple manuscripts where it was determined which commentators' versions would have been available to Newton, which editions Newton might have had access to at Trinity College during his time in Cambridge, and what edition actually matched Newton's citation. Most important was discovering that the running title on page 789 for the 1587 edition matched what initially seemed like a mistake by Newton in noting the correct book of Pliny's work. While the information is in book thirty-three, chapter

48. See Boyle 1673.
49. My thanks to Jason Dean and the Linda Hall Library for digitizing their copy of this book so that there is a publicly available copy that contains those pages. See Boyle 1671.

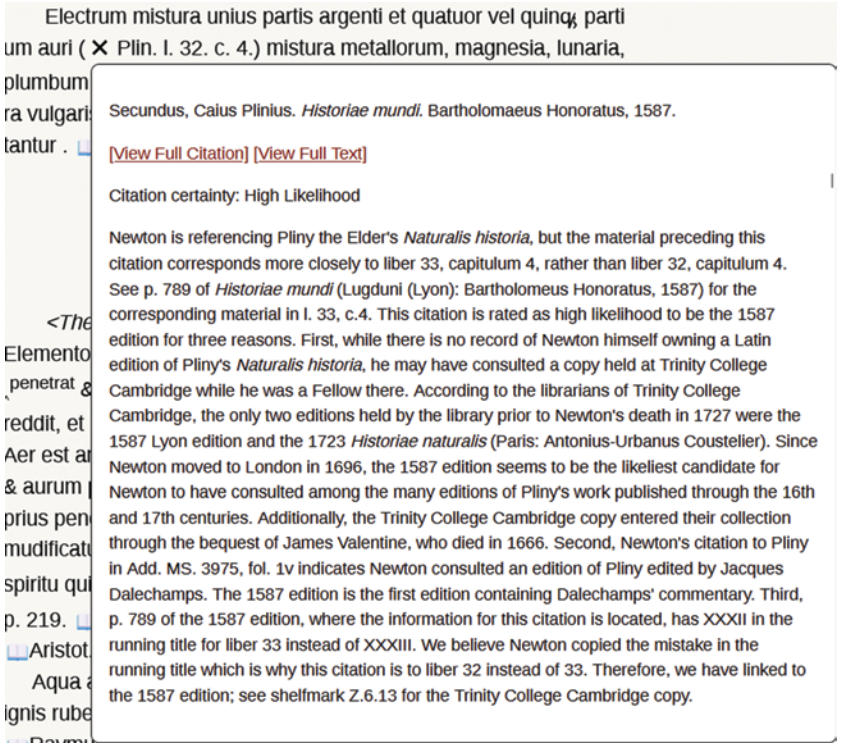


Figure 15. Bibliographic note by author for citation to Pliny in Cambridge, King's College Library, Keynes MS. 30/1, charta 32*r*.

four, the running title on page 789 has "NATVRAL. HIST. LIB. XXXII." (Plinius Secundus 1587, 789), matching Newton's "L. 32. C. 4." Without the note, this careful analysis would be inaccessible, readers would have a difficult time finding the passage in the 901-page book, and it would seem that our choice of the 1587 edition was at random.[50]

Dating manuscripts

The next goal, dating the manuscripts, is slowly being completed as manuscripts' citations are re-encoded according to the new system or encoded for the first time. Once a manuscript has been completed, we can find the TPQ according to the citations computationally. First, the manuscript corpus is queried as a whole to extract the metadata associated

50. See Plinius Secundus 1587.

	A	B	C	D	E
1	ALCH	shelfmark	source	date	certainty
2	ALCH00001	MS. 12	Zetzner1660	1660	verified
3	ALCH00001	MS. 12	Zetzner1660	1660	verified
4	ALCH00001	MS. 12			ambiguous
5	ALCH00001	MS. 12	Zetzner1661	1661	unknown
6	ALCH00001	MS. 12	Zetzner1660	1660	verified
7	ALCH00001	MS. 12	Zetzner1661	1661	unknown
8	ALCH00001	MS. 12			ambiguous
9	ALCH00001	MS. 12	Zetzner1659d	1659	unknown
10	ALCH00001	MS. 12	Artis1610_2	1610	verified
11	ALCH00001	MS. 12	Zetzner1659d	1659	unknown
12	ALCH00001	MS. 12	Zetzner1659d	1659	unknown
13	ALCH00001	MS. 12	Zetzner1659a	1659	unknown
14	ALCH00001	MS. 12	Zetzner1659e	1659	verified
15	ALCH00001	MS. 12	Musaeum_Hermeticum1625	1625	high
16	ALCH00001	MS. 12	Zetzner1660	1660	unknown
17	ALCH00001	MS. 12	Artis1610_1	1610	verified
18	ALCH00001	MS. 12	Artis1610_1	1610	verified
19	ALCH00001	MS. 12	Artis1610_1	1610	verified
20	ALCH00001	MS. 12	Artis1610_1	1610	verified
21	ALCH00001	MS. 12	Artis1610_1	1610	verified

Figure 16. Screenshot of citation metadata table.

with each citation: the ALCH identifier and shelfmark of the manuscript in which it occurs, the source's identifier, the publication date of the source extracted from the bibliography, and the citation certainty.[51] This generates a long XML file containing the corpus' citation data which is then converted to a spreadsheet (see the result in Figure 16).[52] Then one may use a pivot table in a spreadsheet program to calculate the max value of "date" for a given manuscript filtered to "verified" citations only (Figure 17, below). This maximum value is the TPQ for the manuscript.

For example, the calculated TPQ for ALCH00044 (Cambridge, King's College Library, Keynes MS. 55) is 1678, ALCH00045 (Cambridge, King's College Library, Keynes MS. 56) is 1680, and ALCH00046 (Cambridge, King's College Library, Keynes MS. 57) is 1686. ALCH00044 has a TPQ of 1678 because the source with the latest publication date is *Ripley Reviv'd* by George Starkey under the pseudonym Eirenaeus Philalethes, which was published in 1678 by William Cooper in London. The other two sources

51. The manuscript corpus is queried using XQuery, a query language for extracting elements, attributes, and other data from XML. The ALCH identifier is an identifier assigned by The Newton Project at Oxford. Identifiers begin with four letters indicating the subject matter (ALCH for alchemy, THEM for theological materials) followed by five numbers.
52. The conversion from XML to CSV is accomplished using the eXstensible Stylesheet Language (XSLT).

	A	B	C
1	certainty	verified	
2			
3	ALCH	Max - date	
25	ALCH00042	1689	
26	ALCH00043	1659	
27	ALCH00044	1678	
28	ALCH00045	1680	
29	ALCH00046	1686	
30	ALCH00049	1661	

Figure 17. Screenshot of pivot table showing calculated TPQ.

with verified citations are *Secrets Reveal'd* by Starkey (London: William Cooper, 1669) and *Novum lumen chymicum* by Michael Sendivogius (Genevae: Ioannes de Tournes, 1639), but since *Ripley Reviv'd* was published later, it serves as the benchmark for the TPQ. In ALCH00045, nineteen different sources with publication dates ranging from 1566 to 1680 have verified citations. The earliest source is a compilation called *Ars chemica* (Argentorati: Samuel Emmel, 1566), and the latest source, which determined the TPQ, is another compilation edited by John Frederick Houpreght called *Aurifontina chymica* (London: William Cooper, 1680).[53] ALCH00046 has a similarly diverse array of sources with verified citations (fourteen total), but the latest published source is Dickinson's *Epistola ad Theodorum Mundanum* (Oxoniae: E Theatro Sheldoniano, 1686). The four verified citations to Dickinson push the TPQ back to 1686. Without these citations, the TPQ would be 1678, since the next latest source is *Ripley Reviv'd*, the publication setting ALCH00044's TPQ.[54]

Notably, not all manuscripts will be able to have a TPQ calculated via citations because not all manuscripts contain verified citations. Other methods (paleographic, ink, and watermark analysis) will need to be applied to those manuscripts.

53. See Ars chemica 1566 and Houpreght 1680.

54. See Dickinson 1686. In fact, Dickinson's *Epistola* is extremely useful for dating even when there is a citation with unknown likelihood (which is possible with unpaginated citations because there is a 1687 edition) because 1686 is the first edition. The *Epistola*'s inclusion in one of Newton's manuscripts no matter the certainty from unknown likelihood to verified generally provides a good argument for a minimum TPQ of 1686.

When the TPQ is calculated for the entire manuscript corpus, we can begin to order manuscripts and see how the manuscripts spread out across Newton's lifetime. Figure 18 (below) shows all the manuscripts that currently have encoded citations, both under the old system (orange squares) and the new system (blue circles), plotted according to their estimated TPQ using verified citations in the case of the new system and all citations in the old system. Given that a significant number of manuscripts still need to be re-encoded according to the new system, it is harder to draw conclusions about the development of Newton's alchemical work from this graph. Once all the manuscripts are encoded, an updated version of this visualization should show periods of greater and lesser activity in Newton's alchemical work.

Those TPQs dated earlier than the early to mid-1660s tell us little since those prior to 1643 were before Newton's birth, and Newton's interest in chymistry did not begin to solidify until somewhere between about 1660 and 1666 (Newman 2019, 89–96). Like those manuscripts for which a TPQ cannot be calculated, other methods will be necessary to date

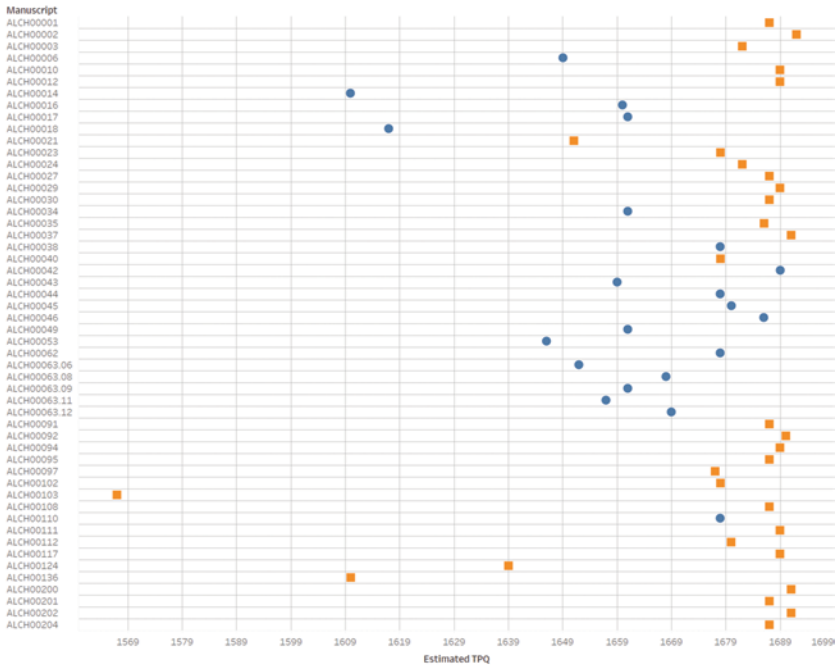


Figure 18. Estimated TPQ of each manuscript for which a TPQ can be calculated. Blue circles are manuscripts that have been fully re-encoded according to the new system; orange squares are manuscripts that are still encoded under the old system.

them. One existing conjecture that is confirmed by the graph, however, is that the different manuscript bundles composing Jerusalem, National Library of Israel, MS. Var. 259 (ALCH00063) were likely composed earlier in Newton's alchemical career (Newman 2019, 23, 98n27, 197). ALCH00063.06, .08, .09, .11, and .12 (bundles 6, 8, 9, 11, and 12 of MS. Var. 259) all have an estimated TPQ earlier than 1670.

Currently, just 50% of manuscripts (twenty-one of forty-two) that have been encoded according to the new system have verified citations that can serve as the basis for TPQ calculations. However, because the new encoding system allows us to indicate high likelihood citations, we can also decide to include high likelihood citations in the calculation of TPQ. Doing so permits TPQs to be assigned to more manuscripts and to assign a later TPQ to others. The inclusion of high likelihood citations into the calculation allows for nine additional manuscripts to be assigned TPQs, and two other manuscripts can be assigned a later TPQ than that calculated only via verified citations.[55] Figure 19 shows this updated view and reveals more manuscripts with TPQs after the mid-1660s, providing a better picture of Newton's alchemical work.

Including high likelihood citations admittedly introduces a level of uncertainty into the analysis, but this is a measured risk that is outweighed by the benefits. There is still a good level of confidence that we know the specific edition for high likelihood citations even if we lack the greater certainty of verified citations.

In addition to TPQ dating, we can also estimate the relative order of composition of Newton's manuscripts using Newton's paginated citations to his own manuscripts versus print sources. Citations to manuscripts are treated exactly the same as the print citations but emphasize that Newton is referencing one of his own manuscripts in the bibliographical note. Verified citations among manuscripts make it possible to reason that the manuscript being cited was composed before the manuscript containing the citation. For example, Cambridge, King's College Library, Keynes MS. 12 cites *Septimana philosophica* by Michael Maier with paginated citations. This text exists in print, but the cited page numbers do not line up with the printed

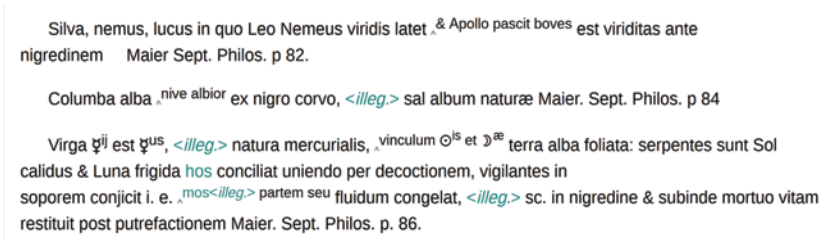
55. The additional manuscripts that have a TPQ when high likelihood citations are included are ALCH00004, ALCH00008, ALCH00009, ALCH00026, ALCH00055, ALCH00063.03, ALCH00063.07, ALCH00063.10, and ALCH00109. The two manuscripts that have later TPQs when high likelihood citations are included are ALCH00017 (pushed from 1661 to 1672) and ALCH00043 (1659 to 1678) due to citations to *Bibliotheque des philosophes chymiques* (Argentorati: Sumptibus Lazari Zetzneri, 1672; see S. D. E. M. 1672) and *Ripley Reviv'd* (London: William Cooper, 1678; see Philalethes 1678).

Figure 19. Estimated TPQ of each manuscript for which a TPQ can be calculated using both high and verified citations where available. Blue circles are manuscripts that have been fully re-encoded according to the new system; orange squares are manuscripts that are still encoded under the old system.

text. Some keyword searching of the *Chymistry* corpus revealed Cambridge, King's College Library, Keynes MS. 32 as Newton's manuscript synopsis of the *Septimana philosophica*. Newton had paginated the manuscript, and the cited page numbers in Cambridge, King's College Library, Keynes MS. 12 match this manuscript copy (see Figures 20 and 21, below).[56]

Based on the three citations to Cambridge, King's College Library, Keynes MS. 32, we assume that Cambridge, King's College Library, Keynes MS. 12 was composed after Cambridge, King's College Library,

56. Finch Collins discovered that the print source did not work while re-encoding Cambridge, King's College Library, Keynes MS. 12, and we collectively determined that Cambridge, King's College Library, Keynes MS. 32 was the source at one of our weekly encoding issues meetings.

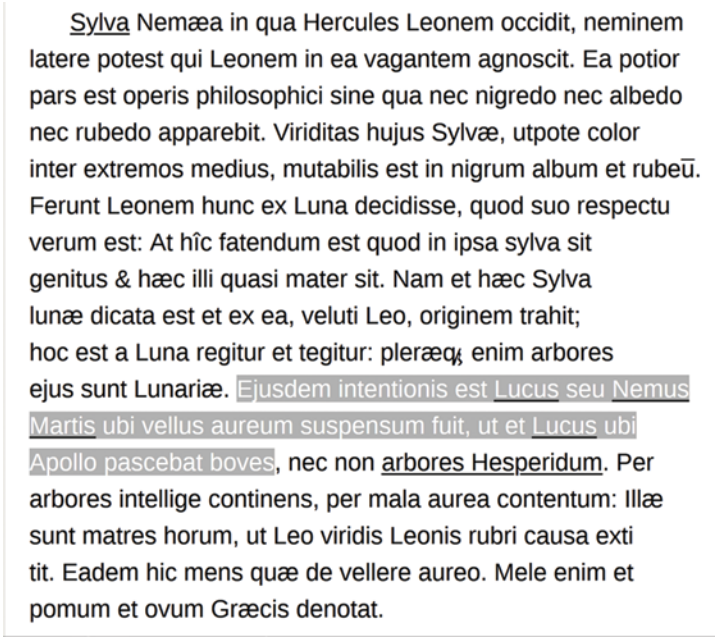


Silva, nemus, lucus in quo Leo Nemeus viridis latet ^& Apollo pascit boves est viriditas ante nigredinem Maier Sept. Philos. p 82.

Columba alba ^nive albior ex nigro corvo, <illeg.> sal album naturæ Maier. Sept. Philos. p 84

Virga ☿ij est ☿us, <illeg.> natura mercurialis, ^vinculum ☉is et ☽æ terra alba foliata: serpentes sunt Sol calidus & Luna frigida hos conciliat uniendo per decoctionem, vigilantes in soporem conjicit i. e. ^mos<illeg.> partem seu fluidum congelat, <illeg.> sc. in nigredine & subinde mortuo vitam restituit post putrefactionem Maier. Sept. Philos. p. 86.

Figure 20. Three citations in Cambridge, King's College Library, Keynes MS. 12, charta 6*v* to Maier's *Septimana philosophica* in *Chymistry of Isaac Newton* transcription.



Sylva Nemæa in qua Hercules Leonem occidit, neminem latere potest qui Leonem in ea vagantem agnoscit. Ea potior pars est operis philosophici sine qua nec nigredo nec albedo nec rubedo apparebit. Viriditas hujus Sylvæ, utpote color inter extremos medius, mutabilis est in nigrum album et rubeū. Ferunt Leonem hunc ex Luna decidisse, quod suo respectu verum est: At hîc fatendum est quod in ipsa sylva sit genitus & hæc illi quasi mater sit. Nam et hæc Sylva lunæ dicata est et ex ea, veluti Leo, originem trahit; hoc est a Luna regitur et tegitur: pleræq; enim arbores ejus sunt Lunariæ. Ejusdem intentionis est Lucus seu Nemus Martis ubi vellus aureum suspensum fuit, ut et Lucus ubi Apollo pascebat boves, nec non arbores Hesperidum. Per arbores intellige continens, per mala aurea contentum: Illæ sunt matres horum, ut Leo viridis Leonis rubri causa exti tit. Eadem hic mens quæ de vellere aureo. Mele enim et pomum et ovum Græcis denotat.

Figure 21. The cited passage on p. 82 of Cambridge, King's College Library, Keynes MS. 32 (charta 41*v*) in *Chymistry of Isaac Newton* transcription.

Keynes MS. 32. Once either manuscript is re-encoded according to the new system, we may be able to use their relative ordering relationship to make inferences about their composition date.

However, only the later part of Cambridge, King's College Library, Keynes MS. 12 may have been composed after Cambridge, King's College Library, Keyne MS. 32. Cambridge, King's College Library, Keynes MS. 12 is formed of two sheets folded in quarto style. The first sheet (chartae 1*r*–4*v*) contains paleographic evidence suggesting a TPQ of 1673 or

earlier.[57] Yet, there are verified citations in the manuscript to Michael Maier's *Secretioris naturae secretorum scrutinium chymicum* (Francofurti: Impensis Georgii Heinrici Oehrlingii) published in 1687.[58] This would appear to be a contradiction except for the fact that these citations to Maier and the citations to Cambridge, King's College Library, Keyne MS. 32 occur on charta 6*v* which is on the second sheet of Cambridge, King's College Library, Keynes MS. 12. In other words, the first sheet of Cambridge, King's College Library, Keynes MS. 12 may predate Cambridge, King's College Library, Keynes MS. 32 while the second sheet follows it. As of right now, analysis for TPQ dating has not gone to the more granular level of sheets outside of this manuscript, but it would be possible to do so in the future. Regardless, this example demonstrates the importance of combining types of evidence (paleographical, citational, and codicological) since it initially seemed the citational evidence contradicted paleographic evidence.

Newton's usage of sources

The analysis of Newton's use of sources, the last goal of the citation work, can proceed in many different directions and at different scales, from the individual manuscript to the whole corpus. Preliminary analyses begin to reveal the most common works and authors for Newton, patterns in the usage of different editions of the same work, the different purposes manuscripts served for Newton, and how Newton incorporated sources into his alchemical thought. These preliminary findings rely on verified, high likelihood, and unknown likelihood citations since all can at least express the author and/or work referenced by the citation. Again, the inclusion of certainty into the encoding framework has permitted us to encode our claims about the works Newton used even when the edition is unclear, providing a more comprehensive dataset.

Taking the corpus as a whole, Newton's citations demonstrate his preference for specific alchemical compilations and certain authors.[59] Table 2 (below) shows the number of citations to a specific source and the number of distinct manuscripts it appears in for all sources appearing in at least twenty manuscripts regardless of the encoding system used.

57. This sheet contains unbarred Saturn symbols, which indicates a TPQ of 1673 or earlier (Newman 2019, 111n67, 226n11, 504).

58. See Maier 1687.

59. Given that the identification of the work is usually right under the older encoding system even if the edition is wrong, the conclusions presented in this paragraph are based on all manuscripts regardless of whether they have been re-encoded.

Table 2. Sources appearing in at least twenty distinct manuscripts.

Source	Author	Total Citations	Distinct Manuscripts
Artis auriferae, vol. 1 (1610)	Compilation	1,006	32
Artis auriferae, vol. 2 (1610)	Compilation	811	30
Ripley Reviv'd (1678)	Eirenaeus Philalethes (George Starkey)	750	30
Theatrum chemicum, vol. 6 (1661)	Compilation	696	28
The Marrow of Alchemy (1654)	Eirenaeus Philalethes (George Starkey)	266	26
Theatrum Chemicum Britannicum (1652)	Compilation	460	26
Novum lumen chymicum/ Tractatus de sulphure (1639)	Sendivogius	214	24
Theatrum chemicum, vol. 5 (1660)	Compilation	433	21
Theatrum chemicum, vol. 1 (1659)	Compilation	280	21
Secrets Reveal'd[60]	Eirenaeus Philalethes (George Starkey)	126	21

The most popular author by far is George Starkey, who published under the pseudonym "Eirenaeus Philalethes". Three different works by Starkey — *Ripley Reviv'd*, *The Marrow of Alchemy*, and *Secrets Reveal'd* — account for 1,142 of the total 10,382 citations encoded (11%).[61] This confirms Newman's assertion that Starkey was one of the most important authors for Newton's alchemical work (2019, 16). Except for Sendivogius, all other widely cited sources are alchemical compilations: the *Artis auriferae*, the *Theatrum chemicum*, and the *Theatrum Chemicum Britannicum*.[62] Many of the works included inside these compilations are much shorter than book-length works like Starkey's, but

60. An additional 242 citations in seventeen different manuscripts exist for *Introitus apertus* (1667) by Starkey. *Secrets Reveal'd* is a revised version in English of the original Latin *Introitus apertus*.
61. If the *Introitus apertus* citations are added, this rises to 13%.
62. The *Artis auriferae* and the *Theatrum chemicum* both have multiple editions, but paginated citations show an overwhelming preference for the 1610 edition of the *Artis auriferae* and the 1659–1661, 6-volume edition of the *Theatrum chemicum*. Thus far, no paginated citation can be traced to any of the earlier editions for either compilation.

compilations clearly represented an important body of knowledge for Newton.[63] Further, though this analysis is based on manuscripts encoded according to either system, the same ten sources appear as the most popular even if the corpus is restricted to just the manuscripts encoded in the new system. The lack of change confirms Newton's heavy use of these particular sources.

Analysis of Newton's citation patterns also allows speculation about when Newton had access to and used certain editions of particular works, giving us insight into his access to books and his notetaking habits. Returning again to Jean d'Espagnet's *Arcanum hermeticae philosophiae*, the form of Newton's citations and estimated TPQ of the manuscripts which cite the work suggest that Newton initially used one edition of the *Arcanum hermeticae philosophiae,* possibly the one found in the *Bibliotheca chemica contracta* compilation, and then he acquired a copy of one of the two 1642 Parisian editions somewhere between 1678 and 1680.[64]

The evidence for constructing this argument is found in Table 3 (below). It shows all the manuscripts that cite *Arcanum hermeticae philosophiae*, whether the edition used is known (the two Parisian editions are considered together here since one is a line-by-line reprint of the other), the number of citations, and the form of citation (page number, section indicator, or author name). The table also lists whether the manuscript contains unbarred or barred Saturns (ħ), which is a paleographic estimator of dating.[65] The presence of unbarred Saturns indicates a TPQ of about 1673 or earlier, while barred Saturns indicate a TPQ after approximately 1674 (Newman 2019, 111n67, 226n11, 504). The last column of the table gives the estimated TPQ calculated by citations or paleography.[66]

63. Kassell in her study of the 17th-century English bookseller William Cooper's catalogs of alchemical books notes that thirty-five of 544 books in his catalogs contained more than one text, but that these thirty-five contributed 157 of 701 titles (2011, 70). In other words, less than 7% of the volumes contributed 22% of the titles. Compilations were an efficient way to obtain many different works.
64. See Albineus 1653 for a copy of the *Bibliotheca chemica contracta*.
65. No Unicode code point exists for the unbarred Saturn, but it is essentially the same as the barred Saturn pictured above in parentheses, just without the cross stroke. Within the *Chymistry* project's own "Newton Sans" font, a character has been created for the unbarred Saturn within the Unicode Private Use Area.
66. ALCH00063-05 (Jerusalem, National Library of Israel, MS. Var. 259, bundle 5), entirely consists of unknown likelihood citations to d'Espagnet, but Newton's exclusive use of unbarred Saturns in the manuscript points to a date of composition of 1673 or earlier. All other manuscripts use citations to calculate the TPQ.

Table 3. All manuscripts that cite d'Espagnet, the form of the citations, and the estimated TPQ.[67]

Manuscript (ALCH)	Edition of D'Espagnet	No. of citations	Page numbers	Section	Author name	Unbarred Saturn	Barred Saturn	Estimated TPQ[68]
ALCH00008	unknown	17		x		3	0	1667
ALCH00063.12	unknown	2		x	x	4	0	1669
ALCH00063.05	unknown	44		x		5	0	1673 (or earlier)
ALCH00024	unknown	1		x		0	5	1678
ALCH00038	unknown	11			x	0	5	1678
ALCH00045	Paris 1642	11	x			0	11	1680
ALCH00046	Paris 1642	2	x			0	3	1686
ALCH00027	Paris 1642	4	x	x		0	2	1686
ALCH00091	Paris 1642	2	x			0	0	1687

(*Continued*)

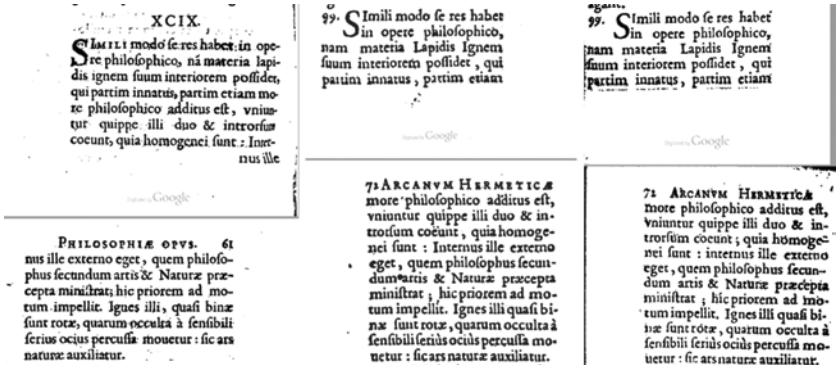
67. ALCH00002 (Cambridge, King's College Library, Keynes, MS. 13) mentions d'Espagnet by name (charta 1*r*), but since this manuscript is essentially just a listing of many authors, it has no real information on his use of the source and so is not relevant to this analysis.
68. ALCH00008, ALCH00063-12, ALCH00063-05, ALCH00038, ALCH00045, and ALCH00046 have been re-encoded according to the new encoding system and so the estimation of the TPQ is based on the new encoding. The other manuscripts have not been fully re-encoded, and the TPQ is based on hand-checking to find the latest source that would count as a verified citation.

Table 3. Continued.

ALCH00095	Paris 1642	2	x			0	0	1687
ALCH00108	Paris 1642	3	x			0	5	1687
ALCH00201	Paris 1642	61	x			0	0	1687
ALCH00204	Paris 1642	5	x			0	3	1687
ALCH00202	Paris 1642	45	x			0	8	1687
ALCH00010	unknown	1		x		0	5	1689
ALCH00094	Paris 1642	3	x			0	29	1689
ALCH00117	Paris 1642	1	x			0	7	1689
ALCH00200	Paris 1642	55	x			0	9	1689
ALCH00037	Paris 1642	1	x			0	4	1691

Examining the table, we first see that the paleographic and citational evidence for the TPQ coincide. All manuscripts with a citation-based TPQ with unbarred Saturns are earlier than 1673, and all those with barred Saturns have a citation-based TPQ of 1674 or later. Next, looking at the patterns in the citation forms, all citations with section numbers or just d'Espagnet's name occur in manuscripts with a TPQ of 1678 or earlier with the exception of ALCH00010 (Cambridge, King's College Library, Keynes MS. 21). Conversely, all paginated citations match the two Parisian editions, and all the manuscripts in which they occur have an estimated TPQ of 1680 or later. In other words, there is a change in citational practice that strongly correlates with the period of composition.

A possible explanation for this change is that prior to roughly 1678, Newton had unstable access to an edition of the *Arcanum hermeticae philosophiae,* and that by 1680 he had acquired stable access to one of the two 1642 Parisian editions of the text. Instability meant that Newton needed to cite the text in such a way that citations were interoperable between multiple editions, while stability (likely through ownership) signified that he could use edition-specific references. The *Arcanum hermeticae philosophiae* facilitates interoperable citations through section numbering that is consistent between all editions of the *Arcanum hermeticae philosophiae* (see Figure 22, below). As a result, any citations


XCIX.

SImili modo ſe res habet in opere philoſophico, ná materia lapidis ignem ſuum interiorem poſſidet, qui partim innatus, partim etiam more philoſophico additus eſt, vniuntur quippe illi duo & introrſum coeunt, quia homogenei ſunt: Internus ille

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nus ille externo eget, quem philoſophus ſecundum artis & Naturæ præcepta miniſtrat; hic priorem ad motum impellit. Ignes illi, quaſi binæ ſunt rotæ, quarum occulta à ſenſibili ſerius ocius percuſſa mouetur: ſic ars naturæ auxiliatur.

99. SImili modo ſe res habet in opere philoſophico, nam materia Lapidis Ignem ſuum interiorem poſſidet, qui partim innatus, partim etiam

72 ARCANVM HERMETICÆ more philoſophico additus eſt, vniuntur quippe illi duo & introrſum coeunt, quia homogenei ſunt: Internus ille externo eget, quem philoſophus ſecundum artis & Naturæ præcepta miniſtrat; hic priorem ad motum impellit. Ignes illi quaſi binæ ſunt rotæ, quarum occulta à ſenſibili ſerius ocius percuſſa mouetur: ſic ars naturæ auxiliatur.

99. SImili modo ſe res habet in opere philoſophico, nam materia Lapidis Ignem ſuum interiorem poſſidet, qui partim innatus, partim etiam

72 ARCANVM HERMETICÆ more philoſophico additus eſt, vniuntur quippe illi duo & introrſum coeunt; quia homogenei ſunt: internus ille externo eget, quem philoſophus ſecundum artis & Naturæ præcepta miniſtrat; hic priorem ad motum impellit. Ignes illi quaſi binæ ſunt rotæ, quarum occulta à ſenſibili ſerius ocius percuſſa mouetur: ſic ars naturæ auxiliatur.

Figure 22. Section 99 of the *Arcanum hermeticae philosophiae* in (left to right) *Bibliotheca chemica contracta* (Genevae: Sumpt. Ioannis Ant. & Samuelis de Tournes, 1653), *Enchiridion physicae restitutae* (Parisiis: n.p., 1642), *Enchiridion physicae restitutae* (Parisiis: viduam Nic. de Sercy, 1642). All are screenshots from Google Books from the National Library of the Czech Republic, the Bavarian State Library, and the British Library, respectively.

Newton made using section headings prior to acquiring one of the 1642 Parisian editions were still functional even when he lost access to the borrowed edition. Further, during this unstable period, Newton could have switched between any number of editions since the form of reference would have worked for them all. However, a probable candidate for the unstable period is the 1653 or 1654 edition of Nathan Albineus' alchemical compilation *Bibliotheca chemica contracta*, which Newton is known to have used earlier in his alchemical career (Newman 2019, 182n3).

Later, around 1680, Newton obtained permanent or at least more long-term, stable access to one of the 1642 Parisian editions because he began to use page numbers. If he was not going to lose access to his copy of d'Espagnet, there was no reason to continue using section numbers. Newton could provide a more precise form of citation using page numbers, and his older citations using section numbering were still perfectly serviceable since the 1642 Parisian editions use the common section numbering system. Subsequently, Newton either discarded his copy of one of the 1642 editions or it was not inventoried at his death, since it does not appear in Harrison's catalogue of Newton's library (1978). The lack of documentation in Harrison demonstrates that the encoding system is also useful for identifying editions and works used by Newton even if there is no explicit record of ownership. Regardless, this example demonstrates that combining TPQ computations enabled by the new encoding system with closer readings of Newton's citation forms can reveal new insights into Newton's source usage down to the level of the edition and his habits for referencing.

Lastly, analysis of Newton's citations across the entire corpus will contribute to knowledge about Newton's scholarly practices in regard to alchemical literature. Initial analysis of trends in the number of distinct sources Newton used in a manuscript points to two general habits. First, Newton created different manuscripts for different purposes to support his alchemical studies, such as manuscript copies of particular texts, reading notes of particular authors or works, syntheses of several different works and authors, and reference indices. These differences in purpose affected how Newton used his sources in a particular manuscript and therefore his citation patterns. Figure 23 (below) plots manuscripts by their TPQ (using verified citations if under the new system) on the x-axis and the size of the dot corresponds to the number of unique sources Newton used in the manuscript. The number of sources varies quite widely, from a single source to eighty sources.

These single source manuscripts tend to be Newton's manuscript copies of a particular source. For example, Cambridge, King's College Library,

Figure 23. Distinct number of sources used by Newton per manuscript with estimated TPQ. Orange circles for old system and blue for new.

Keynes MS. 23 (ALCH00012), is a Latin translation of Limojon de Saint-Didier's *Le Triomphe Hermètique* (1689).[69] Given that the first edition of *Le Triomphe Hermètique* was not published until 1689, this is a fairly late example of one of Newton's manuscript copies. Manuscripts using just one or a few sources might also be Newton's reading notes, generally consisting of excerpted passages of interest. Cambridge, King's College Library, Keynes MS. 17 (ALCH00006) contains excerpts from various texts by Ripley, specifically from the collected Latin edition of Ripley's

69. This manuscript is another example of the wrinkle caused by Newton's various linguistic capabilities. In theory, citations to Saint-Didier's work could come from *Le Triomphe Hermètique* directly, or potentially Cambridge, King's College Library, Keynes MS. 23. Generally speaking, however, the project's preference would be to link to the printed text, since that preceded the manuscript and is therefore a more secure marker for dating.

works published in 1649 (Cassellis: Typis Jacobi Gentischii).[70] Similarly, Jerusalem, National Library of Israel, MS. Var. 259, bundle 6 contains excerpts from various English alchemical texts, all very likely copied from the *Theatrum Chemicum Britannicum* (London: J. Grismond for Nathaniel Brooke, 1652).

This type of notetaking aligns well with what was taught at Cambridge before and during Newton's time as a student there. William Newman connects the style of notes in Jerusalem, National Library of Israel, MS. Var. 259, bundle 11 to Richard Holdsworth's handbook "Directions for a Student in the Universitie". Holdsworth was the Master at Emmanuel College prior to Newton's entrance at Trinity, and Newman notes (among other characteristics) the similarity between Holdsworth's instruction to "collect all the remarkable things" from what students were reading and Newton's use of the heading "Things remarkable" in MS. Var. 259, bundle 11 (Newman 2019, 99; Fletcher 1956, 2: 651). Even more striking though is Holdsworth's instruction:

> Ever as you find them [passages of interest] promiscuously, especialy if out of the same book, in the title space set downe the name of the Authour with the book, or Cap: & after every Collection, the number of the page, or Section whence it is taken, that you may speedily recourse to the Authour him self upon occasion. (Fletcher 1956, 2: 651)

The advice to note down exactly where a passage came from — down to the page or section — combined with headings consisting of the author, title, and chapter numbers or names is exactly what Newton does in Cambridge, King's College Library, Keynes MS. 17; Jerusalem, National Library of Israel, MS. Var. 259, bundle 6; Jerusalem, National Library of Israel, MS. Var. 259, bundle 11; and numerous other manuscripts. Holdsworth describes the books of notes made in this manner as "books of Collecting" (Fletcher 1956, 2: 651), and this is a very apt term for what Newton does in these manuscripts.

On the other hand, a manuscript with a greater number of sources is more likely to represent a synthesis of alchemical literature by Newton as opposed to a book of collecting. One such manuscript is Cambridge, King's College Library, Keynes MS. 57 (ALCH00046), which incorporates twenty-one unique sources across 162 citations. Here, Newton mixes quoted material with his own prose or freer paraphrases, instead of simply excerpting one

70. See Combach 1649.

text after another. Newton may still quote sources heavily and directly, but the manuscript is not a copy of a single work or something to be used as a reference for important passages. He engages in more critical activities such as comparing the contents of one work with those of others. For example, at one point in Cambridge, King's College Library, Keynes MS. 57, he compares the ratios of earth, water, and air for a process in three different texts: "In eodem processu elementa terræ aquæ et aeris ad opus album sunt ad invicem ut 3, 2, 1 Rosar p. 163 vel 3, 2, 1 1/2 Clangor p 337. vel 3-1/4, 2, 1 1/2 Arnoldi Rosar p 289." (charta 7*v*).[71] This kind of synthesis is properly termed a *florilegium*, which was a habit of medieval and early modern alchemists. The collecting of choice pieces of information; mix of quotations, paraphrase, and original content; and comparison between authors are all characteristic of the genre for alchemy (Newman 2019, 99, 211, 214).[72]

Notably, neither the *florilegia* nor the books for collecting are the same as the humanist practice of commonplace books where excerpts are systematically placed under topical headings (Newman 2019, 211; Yeo 2021, 636; Zedelmaier 2021, 442, 445). For example, Francesco Sacchini and Jeremias Drexel published some of the most influential manuals on excerpting and notetaking in the seventeenth century. Both recommended excerpting notes in the order read, and then re-organizing those notes under topical headings (*loci*) either by recopying them (Sacchini) or creating an index (Drexel) (Blair 2010, 70, 77). Newton did create topical headings in his drafts of the Index Chemicus, a personal index of alchemical references, found in Cambridge, King's College Library, Keynes MS. 30/1–5 (ALCH00200–ALCH00204).[73] In these manuscripts, head words or phrases are followed by numerous bibliographic citations to different sources where those alchemical terms, concepts, or processes are

71. "In the same process, [the amounts of] the elements of earth, water, and fire for the white work are to each other as 3, 2, 1 Rosar p. 163 or 3, 2, 1 ½ Clangor p 337. or 3-1/4, 2, 1 ½ Arnoldi Rosar p 289." Thank you to Jim Voelkel for assistance in translating.
72. Mary Carruthers discusses various non-alchemical medieval *florilegia* such as Hrabanus' *De universe* from the Carolingian period. She states "The purpose of Hrabanus's compilation is not to substitute for the study of original texts, but to provide cues for recollecting material read earlier. This is a convention of the genre, florilegia being understood to be volumes only of extracts, the notes which students took on their reading" (2008, 219).
73. Keynes MS. 30/1 = ALCH00200; Keynes MS. 30/2 = ALCH00201; Keynes MS. 30/3= ALCH00203; Keynes MS. 30/4 = ALCH00204; Keynes MS. 30/5=ALCH00202.

discussed. The references are to print sources not to his own manuscript notes, however, except in cases of his own manuscript copies of a particular source. Cambridge, King's College Library, Keynes MS. 30/1, the manuscript with the most unique sources, contains eighty individual sources for 2,707 citations.[74]

The second general habit revealed by comparing the number of sources Newton used in his manuscripts is that Newton seems to have gradually synthesized more and more alchemical literature together over time. Taking into account both the number of sources and the position of manuscripts according to the estimated TPQ in Figure 23 (above), Newton tends to use more sources in later manuscripts as opposed to earlier ones. This pattern seems to indicate that Newton was moving from just taking reading notes of individual sources (or making his own manuscript copies) to instead gradually incorporating more and more information over time into a personal, collective body of knowledge, and likely without discarded sources either. Newman has noted that Newton was very rarely negatively critical towards his sources either in terms of their content or style (2019, 22–23), so it seems unlikely that many sources were deliberately set aside.

The increase in synthesis over time is also explained by an overall change in Newton's notetaking techniques. Newman has observed that Newton gradually increased his use of *florilegia* with time versus maintaining the Cambridge style of notes seen in Jerusalem, National Library of Israel, MS. Var. 259, bundle 11. Newman states that "Newton's later adoption of alchemical genres as his own favored style of notetaking surely reflects his growing comfort with the riddling language of the adepts and an eagerness to be included in their ranks" (2019, 99). I would argue, however, that even in these *florilegia*, Newton maintained vestiges of his Cambridge student habits because he maintains his generally meticulous dedication to indicating through citations where passages originate, as Holdsworth insists on for his books of collecting. Cambridge, King's College Library, Keynes MS. 35 (ALCH00024), one of Newton's earlier *florilegia* according to Newman, has explicit, paginated citations to numerous sources, as seen in Figure 24 below (2019, 211). These citations oriented Newton to the information's location should he have needed to reconsult the original author, and now they orient us in our reconstruction of Newton's use of sources.

74. This manuscript has not been re-encoded to the new system, but the vast majority of the citations are paginated, so it is more likely that the identification of the sources and the estimated TPQ are correct.

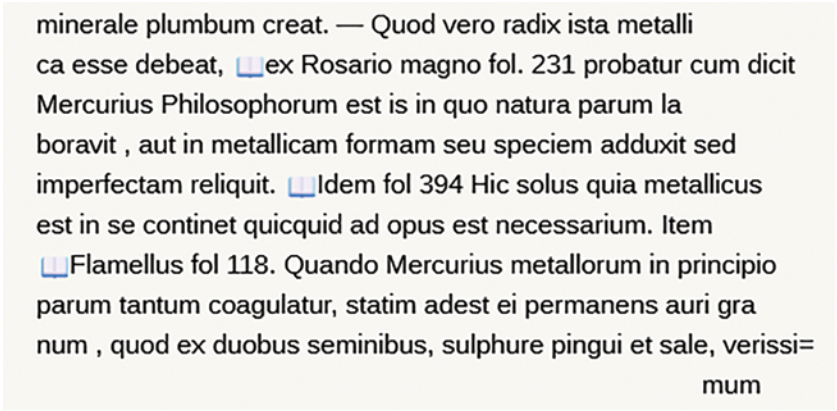
minerale plumbum creat. — Quod vero radix ista metalli
ca esse debeat, ex Rosario magno fol. 231 probatur cum dicit
Mercurius Philosophorum est is in quo natura parum la
boravit , aut in metallicam formam seu speciem adduxit sed
imperfectam reliquit. Idem fol 394 Hic solus quia metallicus
est in se continet quicquid ad opus est necessarium. Item
Flamellus fol 118. Quando Mercurius metallorum in principio
parum tantum coagulatur, statim adest ei permanens auri gra
num , quod ex duobus seminibus, sulphure pingui et sale, verissi=
mum

Figure 24. Passage containing three citations from Cambridge, King's College Library, Keynes MS. 35, charta 7*r* in *Chymistry of Isaac Newton* transcription.

Conclusion

This article has shown citation analysis' usefulness for analyzing Newton's chymical studies while also demonstrating the importance of bibliography to accurate dating via citation analysis. The older citation framework did not account for differences between work, edition, and issue and did not have any way to indicate certainty, creating the potential for estimating manuscripts' TPQ inaccurately. In comparison, the introduction of certainty levels and bibliographic notes provides more information about Newton's sources while still isolating those citations usable for dating.

There are at least 10,000 more citations that remain to be encoded, but in the end, we will be able to expand upon these preliminary analyses and have a detailed view of Newton's sources and when he used them. Besides the methods demonstrated in the data analysis above, other potential methods include a cluster analysis of what sources Newton seems to use in conjunction with each other and why. Other scholars could extend this citation framework to Newton's writings in science, math, and theology, and it could be adopted for analyzing other figures in science or other fields. Citation analysis, when carried out in a way that is sensitive to the bibliographical history of the sources being cited and the citation forms, has the potential to bridge the gap from manuscript to print.

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