Solving an Alchemical Cipher in a Shared Notebook of John and Arthur Dee

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Abstract

This paper builds on a work in progress by Lang and Piorko published in HistoCrypt 2021, which presented a seventeenth-century ciphertext and cipher table discovered in a shared notebook of John and Arthur Dee (Sloane MS 1902). Using Latin statistical models we have successfully deciphered the encrypted text. Our results found the plaintext to consist of 177 Latin words describing a practical experiment for the creation of the alchemical Philosophers' Stone, presented as a chrysopoeic recipe. The encryption method is a variant of a Bellaso/Della Porta style-cipher, agreeing with the paper by Lang and Piorko. After correcting some errors in the seventeenth-century ciphertext and table it was noted that the cipherkey, 45 letters in length, forms part of the original plaintext and is also derived from an alchemical context. This article presents the transcription of the cipher table and ciphertext, the key, and the Latin plaintext, and discusses the decryption process as well as the historical context.

1 Introduction

At the HistoCrypt 2021 conference, Lang and Piorko presented a seventeenth-century cipher with the Latin title *Hermeticae Philosophiae medulla* (Marrow of the Hermetic Philosophy), found in Sloane MS 1902, a shared notebook of John and Arthur Dee (Lang and Piorko, 2021).[1] This notebook is a collection of astrological medical remedies and predictions scribed by English polymath John Dee (1527–1608) and his son, Arthur Dee (1579–1651), who served as Royal Physician to Tsar Mikhail I of the Romanovs. The ciphertext and table in Sloane MS 1902 can be attributed to Arthur Dee based on bibliographical evidence and handwriting analysis, and has been bound upside down in relation to the rest of the manuscript text. A detailed bibliographical description and contextualization of the cipher in Sloane MS 1902 can be found in the 2021 article (Lang and Piorko, 2021).[2]

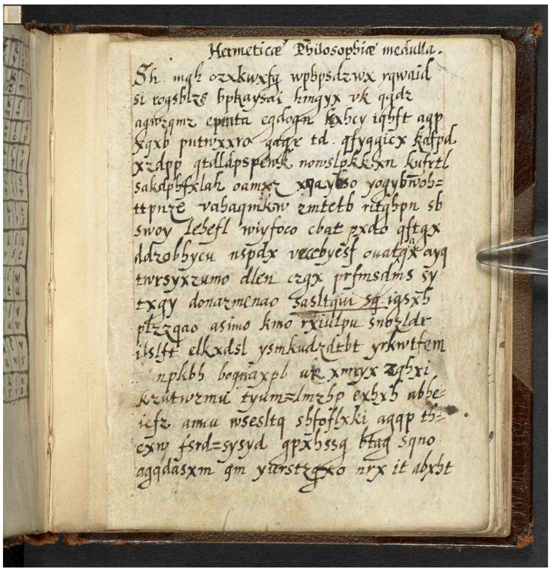

Figure 1: First page of the cipher text with the heading *Hermeticae Philosophiae medulla*. © British Library Board Sloane MS 1902 folio 13v.

2 Solving the Cipher in Sloane MS 1902

The ciphertext (figures 1 and 2) is approximately 1,100 letters long and is entirely comprised of letters from the 24 letters of the Latin alphabet. As

[1]We are grateful to the anonymous reviewers for their useful feedback.

[2]Furthermore, the process of analyzing and decrypting this cipher was published as it went along in a series of blogposts and news articles (Piorko and Lang, 2021; Bean et al., 2021; Piorko, 2021).

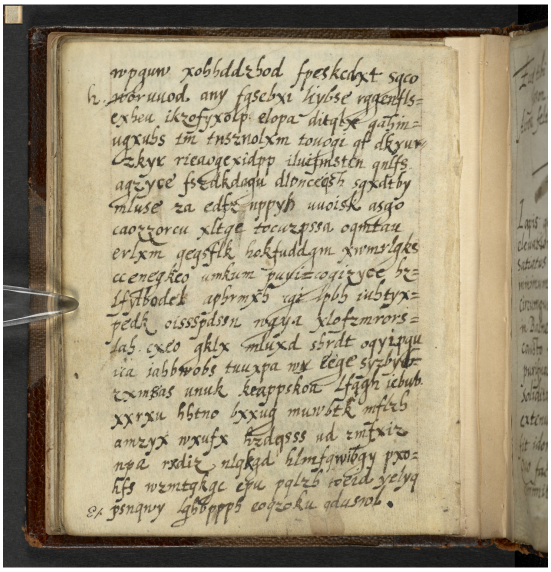

Figure 2: Second page of the cipher text. © British Library Board Sloane MS 1902 folio 13r.

Figure 3: Cipher table (*tabula recta*). © British Library Board Sloane MS 1902 folio 14r.

such, the letters ‘j’ and ‘v’ do not occur at all. It is difficult to distinguish between ‘b’ and ‘h’ in the handwriting of Arthur Dee, and additionally Dee’s encryption contained some errors which could only be resolved after the cipher was solved. The cipher table is located in Sloane MS 1902 on the page adjacent to the ciphertext itself (figure 3), and as noted, appears to correspond to a Bellaso/Della Porta cipher.[3] The table contains 24 different letters; however, ‘I’ and ‘U’ are missing and ‘J’ and ‘V’ are included. This can be accounted for by substituting ‘J’ for ‘I’ and ‘V’ for ‘U’, which was a common typesetting practice in early modern hand-press printing.[4] Arthur Dee’s table contains mistakes, namely that the subrow of the top row (corresponding to ‘AB’) should begin with ‘n’ rather than ‘o’. This results in the entire cipher table being “off” by one letter.[5]

2.1 Cryptographical Analysis

The index of coincidence (IC) confirms the style of cipher as a Bellaso/Della Porta cipher. The initial transcription of the ciphertext contained 1,100 letters and an IC of 0.04365. The IC became 0.04390 when the three occurrences of the letter ‘v’ were changed to ‘u’.

A final transcription, derived after the plaintext was deciphered, has an IC of 0.04360. A completely random plaintext with 26 letters would have an IC of 1/26 or 0.03846; with 24 letters it would be 1/24 or 0.04167. Testing of example Latin and English plaintext enciphered with random Latin/English keywords was also employed to gain insight into whether the encrypted language was Latin. This was performed on two 1,000 letter Latin excerpts from Caesar’s speeches in the Project Gutenberg collection, and two random 1,000 letter English texts.[6]

[3] The cipher was invented by Bellaso in 1552 and published in booklets (1553–1555–1564), see section on historical context and (Buonafalce, 2006). However, it is known as a Della Porta cipher because Della Porta published it in his 1563 book *De Furtivis* without crediting Bellaso, unlike Vigènere who cited him correctly in 1586. As alchemists would have probably known the cipher through Della Porta, we chose the naming convention ‘Bellaso/Della Porta cipher’ for this article.

[4] Bellaso’s 1553 cipher had an alphabet made up of 22 letters, i.e. the Latin letters plus ‘Y’ and ‘Z’. ‘W’ was added to German around the fifteenth century as a consonant variant of ’V’. Trithemius’ 1507 *tabula recta* contained 24 letters, i.e. the Latin letters plus ‘K’, ‘W’, ‘Y’ and ‘Z’. This was could be utilized in both German and English contexts where a 24 letter alphabet was used, i.e. a Bellaso table adapted to 24 letters. The process of splitting the vowels ‘u’ and ‘i’ from their consonant forms ‘v’ and ‘j’ only started in the sixteeth century and was finally established around the eighteenth century. This change was not yet in effect for the cipher table presented here which is why ‘i/j’ and ‘u/v’ were still used interchangeably, causing the alphabet to consist of only 24 different letters.

[5] The American Cryptogram Association (American Cryptogram Association, 2016) provides a simple explanation of how encryption and decryption with this cipher works.

[6] Publicly available Latin language tables from previous similar decryption projects were reused (Bean, 2020). For example, 93 Latin books, or about 30 MB of texts from Project Gutenberg formed the input data for the Latin statistics. We also produced a transcript of Arthur Dee’s printed book, *Fas-*

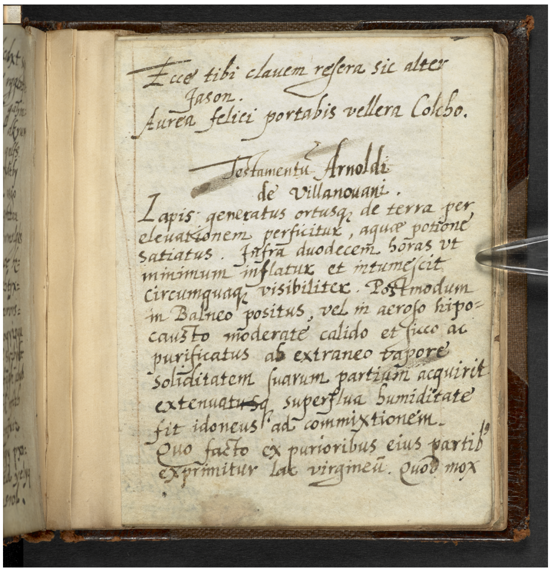
Ecce tibi clauem resera sic alter
Jason.
Aurea felici portabis vellera Colcho.
Testamentu Arnoldi
de Villanouani.
Lapis generatus ortusq; de terra per
eleuationem perficitur, aquae potione
satiatus. Infra duodecem horas vt
minimum inflatur et intumescit
circumquaq; visibiliter. Postmodum
in Balneo positus, vel in acroso hipo-
causto moderate calido et sicco ac
purificatus ab extraneo vapore
soliditatem suarum partium acquirit
extenuatusq; superflua humiditate
fit idoneus ad commixtionem.
Quo facto ex purioribus eius partib
exprimitur lac virgineu. Quod mox

Figure 4: Page with the key phrase (*clavis*) at the top. © British Library Board Sloane MS 1902 folio 12v.

By generating texts made up of 1,099 random letters from a 24 letter Latin alphabet versus a 26 letter English alphabet, the standard deviation was 0.00025 and 0.00026 respectively. Thus, the encrypted text was clearly not 'random' in this sense, as 0.04360 is at least seven standard deviations above the mean IC of 0.04167.

Table 1 contains a frequency count of the letters of the three transcriptions. The first two transcriptions were produced by two of the present authors independently, while the corrected transcription is based on the plaintext.[7]

Next, we attempted to locate the keyphrase which would be integral in decrypting a Bellaso/Della Porta cipher. The first attempt to determine the length of the keyphrase using a Kasiski test did not yield any meaningful results. One big clue to finding the keyphrase was that in a Bellaso/Della Porta cipher with a $2n$ letter alphabet, any letter in the plaintext can map to at most n different letters in the ciphertext, and any letter in the ciphertext can map to at most n different letters in

ciculus Chemicus (1631), based on a digitized copy available on HathiTrust. On *Fasciculus Chemicus* see (Piorko, 2019). The Transkribus Handwritten Character Recognition software provides a number of ready-to-use models for the transcription of early modern print which are especially high performing for Latin texts. With a Character Error Rate of 0.79, the Noscemus GM4 (Fröstl et al., 2022) provided us with a good transcription.

[7]The source code used for the decryption can be found on GitHub (Bean, 2021).

Letter	Transcription A	Transcription B	Corrected transcription
a	53	54	52
b	49	72	35
c	30	24	28
d	50	50	51
e	45	49	44
f	36	37	38
g	59	55	52
h	35	14	48
i	40	40	42
k	39	39	39
l	48	47	49
m	42	43	41
n	32	34	32
o	61	61	60
p	51	51	51
q	34	38	41
r	27	23	28
s	75	74	75
t	46	45	46
u	52	55	52
w	29	27	29
x	74	72	73
y	43	44	44
z	50	51	49

Table 1: Frequency count in different transcriptions.

Cipher	Plain	Key
tocuzpssa	beneficio	ltwgnngtc
rogsblzs	mercurii	ltwgnngt
ueccbyesf	consueuit	ltwgnngtc
ccenegkeo	quocunque	cltwgnngt
gtdldpspewk	naturaliter	nngtcepneip
iubtyxpedk	perficitur	nggcepneip
bpkaysai	partibus	cepneipt
donazmenao	tempestive	gtcepneiat
donazmenao	tempestiva	gtcepneiac

Table 2: Observed cipher / plain / key combinations.

the plaintext, while no plaintext letter can map to itself in the ciphertext.

If the spacing of words in the encrypted ciphertext represented the spacing in the plaintext, the average word length would be around 5.8 (much too long for English, but appropriate for Latin). The decryption was aided by the presence of extremely long words, as there are fewer possible plaintext words that correspond to an encrypted word in the higher length ranges. For example, the longest encrypted word was 'yogyb=nobttpnze', a hyphenated word on the 6th and 7th lines of the first page. This ultimately corresponded to the plaintext word 'ignis=beneficio'.[8]

For each ciphertext word, we determined the most common Latin plaintext word from our dictionary which could correspond to the ciphertext word, considering both Arthur Dee's table and a typical Bellaso/Della Porta cipher table. Now the search for the unknown keyphrase could begin.[9]

To find the keyphrase, we determined the implied keys for each pair of plaintext/ciphertext word, and then started searching for repeated substrings through an automated process. Some of the salient triples are shown in Table 2.

It was clear that the repeated key fragments 'ltwgnngt' and 'cepnei' could not be a coincidence. Concatenating these key fragments together resulted in the key fragment 'ltwgnngtcepneip'. Automated scoring with Latin hexagrams was applied to extend the key backwards and forwards, producing the most plausible Latin plaintext, until the entire 45 letter key was found. The complete keyphrase was determined to be 'tlecnwgtlctppcwtgcggnlelrptwccltwgnngtcepneip'. When compared to the Latin plaintext, we noticed a 45 letter phrase "sic alter Iason aurea felici portabis uellera Colcho" at the end. We immediately recognized the phrase from the page preceding the cipher table in the manuscript (Figure 4), on which Arthur Dee wrote the 45 letter keyphrase. Since we had been working with personal research photographs of the manuscript pages containing the ciphertext and table, the connection to the keyphrase written on folio 12v was not obvious until after the keyphrase had been decrypted using the methods described above.

3 The ciphertext and Table

3.1 Transcription of the Ciphertext

Hermeticae Philosophiae medulla.
Sh mgh ozxkwxfg wphpsdzwx rqwaid
si rogsblzs bpkaysai hmgyx vk qqdz
agwzqmz epmta egdogn kxhcy iqhft agp
xqxb pntwxxro gagx td qfyqgicx kafpd
xzdpp gtdldpspewk nowslpkkxn kufrtl
sakdphfxlah oamxz xqay[?]so yogybwoh=
ttpnze vahaqmkw zmtetb ritghpn sb
swoy lehefl wiyfoco cbat pxdo qftgx
ddzobhycu nspdx veccbyesf ouat[∧a]qx ayq
twrsyxzumo dlen czgx prfmsdms sy
txgy donazmenao <u>sasltqui sg</u> igsxh
plzzqao asimo kmo rxiulpu snozldr
ilslft elkxdsl ysmkudzdtbt yrkwtfem
npkbh bog[?]axpb uk xm[?]yx zghxi
kzutwzmu tyum=lmzhp exhxh abhe=
icfz amcu wsesltq shfoflxki agqp th=
exw fsrd=sysyd gpxhssg btag sqno
agqdasxm qm yurstzgxo nrx it abxht

Page 2
wpguw xohhddzhod fpeskcdxt sgco
horuuod any fgsebxi liybse rggenfls=
exheu ikzofyxolp elopa ditqlx qahin=
ugxuhs tm tnsznolxm touogi qt dkyur
zkyx rieaogexidpp iluifmstcn qnlfs
agzyce fszdkdagu dlonceqsh sgxdtby
mluse za edfz nppyh uuoisk asgo
caozzorcu xltge tocuzpssa oqmtau
erlxm gegsflk hokfuddgm xwmrlgks
ccenegkeo umkum puyi=cogizyce hz=
lfytbodel aphrmxh cgi lpbh iuhtyx=
pedk oissspdssn wgya xlofzmrors=

[8] While this Latin phrase appears frequently in contemporary alchemical texts, it does not occur in the Project Gutenberg texts.

[9] If the key length had been known and Arthur Dee's cipher table did not contain errors, we could have used a hill climbing approach as in Biermann (2018).

lah cxeo gklx mluxd shrdt oqyipgu
ica iahbwobs tuuxpa w[?] eege syzbycb=
zxmsas unuk keappskoa lfagh icbub
xxrxu hhtno bxxug muwbtk mflzh
amzyx wxufx hzdqsss ud zmfxiz
npa rxdiz nlqkgd hlmfqwibgy pxo=
hfs wzmtqkgc cpu pqlzh oeid yelyq
psnqwy lghbppph eoqzoku qduswl

3.2 Transcription of the Table

AB	a o	b p	c q	d r	e s	f t	g u	h w	i x	k y	l z	n m
CD	a p	b q	c r	d s	e t	f u	g w	h x	i y	k z	l m	o n
EF	a q	b r	c s	d t	e u	f w	g x	h y	i z	k m	l n	p o
GH	a r	b s	c t	d u	e w	f x	g y	h z	i m	k n	l o	q p
JK	a s	b t	c u	d w	e x	f y	g z	h m	i n	k o	l p	r q
LM	a t	b u	c w	d x	e y	f z	g m	h n	i o	k p	l q	s r
NO	a u	b w	c x	d y	e z	f m	g n	h o	i p	k q	l r	t s
PQ	a w	b x	c y	d z	e m	f n	g o	h p	i q	k r	l s	u t
RS	a x	b y	c z	d m	e n	f o	g p	h q	i r	k s	l t	w u
TU	a y	b z	c m	d n	e o	f p	g q	h r	i s	k t	l u	x w
WX	a z	b m	c n	d o	e p	f q	g r	h s	i t	k u	l w	y x
YZ	a n	b o	c p	d q	e r	f s	g t	h u	i w	k x	l y	m z

Table 3: Cipher table (verbatim transcription).

3.3 The Key

The key phrase "Sic alter Iason aurea felici portabis uellera Colcho" ("like a new Jason you will carry the Golden Fleece away from the lucky Colchian") is adapted from the last lines of a *sermo*, a long poem in hexameter verse, by Giovanni Aurelio Augurello (1441–1524). The poem is called *Alberto Vonico, Tarvisino Equiti et Iureconsulto* χρυσοποιία *(Chrysopoeia)* and is the *Sermo XI.* in Augurelli's 1505 *editio princeps*.[10] Dedicated to Alberto Ongio, the poem follows a first-person narrative of a lost voyager who achieves the Golden Fleece by tending to a sheep in a cave over an extended period of time. It is a mythological allegory for a chrysopoeic process, i.e. alchemy with the goal of making gold or the Philosopher's Stone (Soranzo, 2020, 35–39, 86–88, 110-121). While the last two lines of the poem include an allusion to the Greek myth of Jason and the Argonauts on their quest for the Golden Fleece, the myth (re-)told in the poem really isn't compatible with this original myth, despite making reference to it. Rather, it can be interpreted as an allegorical rendering of a recipe for making the Philosopher's Stone from an amalgam of gold and mercury. It is likely that Augurelli understood the Golden Fleece as a mythical book ('animal skin') containing the recipe for gold-making (Soranzo, 2020, 218–219).

In Augurelli's poem, the lines read "[in patriam residens] sic alter Iason, aurea felici devexi vellera Colcho", meaning that the lines have been adapted before being used as a cipher key by changing the first person 'devexi' to the second person 'portabis'.[11]

4 Latin Plaintext Decoded

The 177 word Latin plaintext reads as follows.[12]

In ouo diaphano hermetice clauso ex Mercurii partibus nouem et Lune Vulcaniu ires[13] nondum passe[14] parte una fiat amalgamo quoi[15] in Athanore super ignem naturaliter digerentem tandiu constituetur[16], donec materia ignisbeneficio coruinum induat colorem et ille rursus cygneum quod fere infra trilunium fieri consueuit.

Materia sic albificata ovum sine amotione ab igne tempestiue aperiant[17] <ac> solis foliati parte una materie[18] immersa quanta poteris dexteritate firmiter denuo recludas at[19] eodem ignis regimine

[10]Beside the 1505 first edition printed by Aldo Manuzio in Venice, the text was copied in a manuscript in MS Mellon 22 (Beinecke Library at Yale), likely in the hand of Augurelli himself. While the title chosen by the author was χρυσοποιία, the poem was also known as *Chrysopoeia Minor* and at some point confusingly as *Vellus Aurem* which is actually the authorial title of one of Augurelli's earlier poems, also included and discussed in Soranzo's edition (Soranzo, 2020).

[11]Faivre renders Augurelli into English as: "[And returning to my fatherland] as a Jason, I brought across the Golden Fleece from the blessed country of Colchis" (Faivre, 1990; Faivre, 1993). The substitution of 'devexi' to 'portabis' changes the sense to: "you will bear the fleece" and results in making the sentence – which was already somewhat confusing due to the metre – a little awkward grammatically.

[12]Capitalization and punctuation were added to make the text easier to read. However, those weren't part of the ciphertext. Furthermore, u/v were sometimes normalized for better readability.

[13]Should read: *Lunae Vulcani vires*.

[14]*passae*.

[15]Should read: *amalgama quod*.

[16]*tam diu continuetur*.

[17]Should read: *aperias*.

[18]*materiae*.

[19]More likely *ac*.

decoquere sinas, quousque bona[20] materia intensius quam antea nigrefiat[21] nigredo uero illa transeaton[22] albedinem.

Hic si operi finem imposueris, Tincturam Lune habebis. Sed prestat operi continuatiupe[23] splendidum solis solium conscendere et albedinis illius in rubedinee[24] conuersionem prestolari.

Idque tribus plerunque triluniis euenire solet et tunc habes Elixir uere solificum cuius beneficio misera omnis fugatur paupertas egrisque quocunque morbo laborantibus restauratur sanitas.

Duo uero perficitur eodem etiam modo multiplicatur nisi quod solis lucum[25] Elixire suo supplere debeas ac opus abbreviata dum[26] fiat proiectio units[27] super decem, prima tamen semper super solem facta.

Perfice et fruere, Deo denti gratus[28] proximoque egenti benignus.

Sic alter Iason aurea felici portabis uellera colcho.

The text speaks of a 'hermetically sealed egg' which is taken out of an Athanor, a type of alchemical furnace. Colour changes to be observed are described and instructions given for what to do and how long to wait until the various alchemical phases ensue (blackening, whitening and the red phase). The recipe promises either a silver tincture or a gold-making elixir depending on how many steps of the process are carried out and when the process is finally stopped.[29]

5 The Bellaso/Della Porta Cipher in Alchemy

The cipher discovered in Sloane MS 1902 has been correctly identified as a Bellaso/Della Porta type in earlier publications (Lang and Piorko, 2021; Bean et al., 2021). Figure 5 provides a visualization of how this style of cipher can be decrypted manually without the use of computer methods, which is how historical actors such as Arthur Dee would have understood the cipher, using the example of the first few lines of the *Hermeticae Philosophiae medulla*.[30]

Originally attributed to Giambattista della Porta (1535–1615) who first published such a cipher table in his 1563 work *De Furtivis Literarum Notis* (della Porta, 1563, 101), this style of cipher table had actually been published a decade earlier by Giovan Battista Bellaso (*1505) in the form of a booklet (Buonafalce, 2006). Della Porta, in his self-fashioning as a 'popularizer of secrets' (Kodera, 2021), supplies the cipher table (often referred to today as 'Porta table'), instructions for how to use the cipher, and a practical example in *Caput. XVI. Quomodo aliter clavi utendum sit, sine qua scriptum non posset aperiri* (How else a keyphrase should be used without which the writing cannot be accessed) of his cryptography handbook. Della Porta's table consists of two major columns, the first one containing a pair of two subsequent letters of the alphabet per row, which were previously referred to as 'subrows'. This first column of the *tabula recta* is entitled *Literae clavis* (letters of the key) whereas the second one is called *Literae scripti* (letters of the [cipher]text). Unlike the table in Sloane MS 1902, Della Porta's has only 11 reciprocal alphabets. Della Porta's table uses 'I' for both letters 'i' and 'j' as well as 'V' for both letters 'u' and 'v'. Interestingly, Della Porta also omits the letters 'K' and 'W' from his table, suggesting that Della Porta conceived his table to be used exclusively for Latin. This also indicates that Arthur Dee might have copied this adapted Porta table from an English context where the inclusion of letters 'k' and 'w' would be necessary. Thus, the cipher tables of Della Porta and Arthur Dee diverge in the 5th row, although both were created following the same cryptographical design principles. The point of divergence between the alphabets is marked in red in table 4.

The table as presented in the MS Sloane 1902 as shown in Table 3 could not be used directly for deciphering with the Latin key phrase. The final column in each row would have to be corrected so that the letters were sequential (for example, the first row would have to be 'a b c d e f g h i k l m'). Hence, we provided a corrected table in the form

[20] Should be: *tota*.
[21] Should be: *nigra fiat*.
[22] Should be: *transeat in*.
[23] *continuatione*.
[24] Should be: *rubedinem*.
[25] Should be: *locum*.
[26] *ad opus abbreviandum*.
[27] *unius*.
[28] *Deo dando gratias*.
[29] A detailed translation and interpretation of this text are currently being prepared for publication by the authors.

[30] The manual decryption process is as follows: Beginning with the first letter of the key, one locates the relevant row using the *Literae clavis* column of the cipher table. The first letter of the key is 's', thus we choose the 'RS' row, then take the first letter from the ciphertext ('s') to determine that the first plaintext letter is 'i' and so forth, repeating the key as needed as a 'running key'.

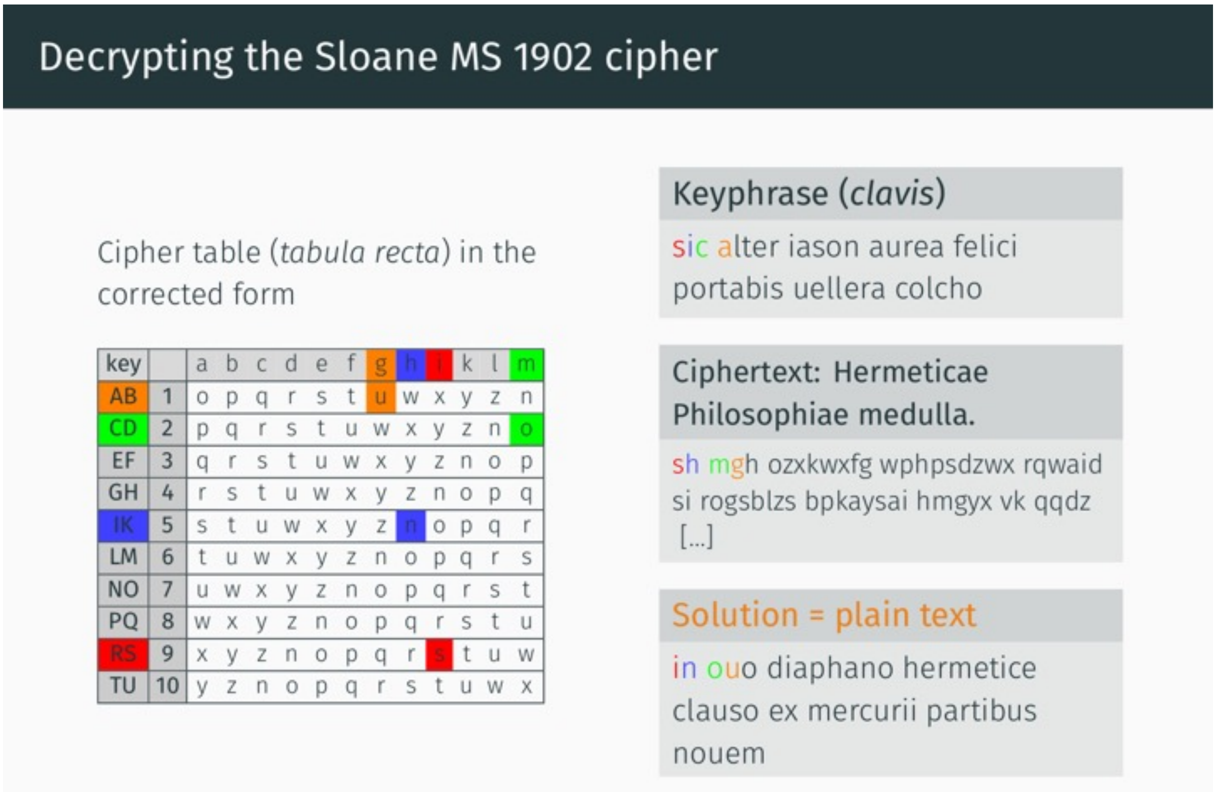

Figure 5: Visualisation of the decryption process for a Bellaso/Della Porta cipher shown on the example of the first line of the Sloane MS 1902 cipher.

Della Porta	**Sloane MS 1902**
AB	AB
CD	CD
EF	EF
GH	GH
IL	JK
MN	LM
OP	NO
QR	PQ
ST	RS
VX	TV
YZ	WX
	YZ

Table 4: Comparison of the *Literae clavis* columns in the cipher tables from Della Porta's *De Futivis* (1563) and Dee's Sloane MS 1902.

of Figure 5.

In the table from *De Furtivis*, the upper half of each ciphertext row (*Literae scripti*) contains the same 11 letters 'a b c d e f g h i l m' whereas in the lower half of each row, the remaining letters of the alphabet are shifted, with each row "slid regularly from left to right, relative to the preceding alphabet" which is a "simplification of a table that had been printed a decade before by Giovan Battista Bellaso in his booklet" (Buonafalce, 2006, 39). In Dee's table, however, since his alphabet includes the letters 'k' and 'w', each row's first line contains the letters 'a b c d e f g h i k l' and then a twelfth letter which alternates in each row ('n o p q r s t u w x y m' in the first line, for example). The shifting process in the second line of each row is similar to Della Porta's, with the first letter of each second line alphabetically following the last letter of the first line. For example, the first line in Dee's 'AB' row ends in 'l n' and the second line starts with 'o p'. Thus, it is likely that Della Porta was not the direct source for Dee's cipher, as it is adapted for the possibility of use in English contexts by adding 'k' and 'w'. However, this is a strange alteration to the cipher table in the context of the encrypted text of *Hermeticae Philosophiae medulla*, as the plaintext is in Latin and not in English and might explain the errors found in the cipher table. This indicates that Arthur Dee copied the entire cipher (table, ciphertext, and keyphrase) from an external source. It can thus be concluded that adapted versions of the Bellaso/Della Porta cipher were shared among an early modern alchemical network. It is likely that variations of the cipher were adapted from Della Porta, as he also published on alchemical distillation and held a certain notoriety among alchemical audiences. This may explain the popularity of Bellaso/Della Porta ciphers among alchemists when ciphers were not generally as widespread a practice in alchemy as they were in other social realms, such as diplomacy.

5.1 Alchemical Secrecy

Alchemical language is an exceptionally rich source of cryptographic stylistic devices, such as *Decknamen* or anagrams (Newman, 1996). Practices of secrecy are integral to alchemical communication (Principe, 2013). Substitution ciphers are employed for this purpose in addition to secretive language. Ciphering practices based on letter substitution might serve a different purpose from the metaphorical language of alchemy despite both shielding alchemical knowledge from the uninitiated. The characteristic metaphorical tropes of alchemy serve another purpose beyond encipherment as a means of authentication integral to alchemical communication practice that cannot be attained through cryptography alone. A true adept was expected to decode and encode knowledge using specific learned alchemical *Decknamen*, providing an opportunity for performative demonstration of secret alchemical knowledge. Ciphering might serve to accentuate this performance of being in the know even further, despite serving practical purposes. Alchemical texts often use encipherment in quite playful ways (Bilak, 2020); however, this is usually seen in emblematic or allegorical texts rather than the straightforward cipher presented in Sloane MS 1902.

Cracking a cipher requires either expert knowledge of mathematics, possession of the correct keyphrase, or at the very least what has been termed by Ellison a certain 'cipher literacy' (Ellison, 2017), none of which were necessarily part of the arsenal of alchemists. While it is rare to discover numeric ciphers in early modern alchemical texts, they do appear in early modern chemical laboratory notebooks (Newman and Principe, 2003). The practical nature of the plaintext recipe of *Hermeticae Philosophiae medulla* found in Sloane MS 1902 could explain the employment of a numerical cipher in addition to the traditional *Decknamen* that are already present in the alchemical recipe for the Philosophers' Stone. Encrypting an alchemical text would have the added benefit of not only shielding trade secrets from the uninitiated but also from other adepts, providing an advantage in the highly competitive alchemical marketplace, the commercial space for 'entrepreneurial alchemy' (Nummedal, 2007). Considering the potential profit to be made from the early modern 'economy of secrets' (Jütte, 2011), it would have been highly beneficial to encode alchemical knowledge to keep it hidden from the prying eyes of the competition.

Alchemical secrecy is a performative gesture and part of what has been labelled 'secrecy as practice' (Vermeir, 2012), as opposed to 'secret as content', i.e. the underlying mode of functioning in cryptography where decrypting the secret is much more important than the rhetoric of secrecy as a performative gesture. Cryptography is a practical, relatively unembellished method of encrypting information, whereas the purpose of alchemical stylistic devices is the interplay of hiding and unveiling. Oftentimes, the performance of the customary 'rhetoric of secrecy' omnipresent in alchemy was just as important as the concealment of information, sometimes more. This is exemplified by Arthur Dee's cipher table in Sloane MS 1902, which would not have been useful for decrypting the text of *Hermeticae Philosophiae medulla*, but would signify that he was aware of contemporary methods of encryption.[31] The cipher in Sloane MS 1902 remains a puzzling example of an alchemical cipher. While we have successfully decrypted the recipe contained within the ciphertext, the question remains of why this particular recipe for the Philosophers' Stone was encrypted as a Bellaso/Della Porta cipher and subsequently copied into a notebook containing astrological medical remedies used by John Dee and Arthur Dee.

[31] Manually testing the decryption process as demonstrated in Figure 5 using the table in its uncorrected form, one would receive 'km lun' instead of 'in ovo' for the first two words, for example.

6 Conclusion

Alchemical ciphers remain an understudied topic in history of science today (Rec, 2014). Accordingly, the historical context for the cipher from Sloane MS 1902 leaves much to be uncovered. Only with the discovery, decryption, and further interpretation and analysis will the alchemical context be revealed and the role of ciphering in alchemical knowledge practices understood. Given the relative scarcity of numerical ciphers and mathematical, substitution-based ciphering mechanisms in alchemical contexts, the cipher presented in this paper is all the more interesting. The cipher table and text titled *Hermeticae Philosophiae medulla* is a unique and puzzling example of Anglicizing a Bellaso/Della Porta cipher for alchemical secrecy, leaving us to wonder why exactly this particular partial recipe for the Philosophers' Stone was transmitted through alchemical scribal networks in this encrypted form. The authors of this paper have future research and publication plans for the translation and interpretation of the encrypted text of *Hermeticae Philosophiae medulla*, and will continue to work on this and other alchemical ciphers to determine the historical implications of alchemical modes of secrecy.

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