From alchemy to modern mineralogy: dating mineral collections via chemical notation

J. Cooke[1]*, A. J. Jeffery[2]

[1] Independent scholar, Ash Mount, Woore, Shropshire, CW3 9RJ

[2] School of Geography, Geology, and the Environment, William Smith Building, Keele University, Keele, Staffordshire, ST5 5BG, U.K.

* Corresponding author

e-mail: john.cooke100@outlook.com

Abstract

Mineral specimens found in historical collections often include specimen labels which may provide vital information on the nature, chemistry, and origin of the material. However, the evolution of chemical notation, particularly during the 18th and 19th centuries, led to a wide range of ways in which a given sample could be adequately documented, many of which may still be found in collections in the present day. Prior to the advent of modern mineralogy, samples were labelled using a complex and sometimes baffling language of alchemical symbols with little meaning to modern scientists. The efforts of notable chemists and mineralogists such as Torbern Bergman, Antoine Lavoisier, John Dalton, and Jöns Jacob Berzelius, began to reform and unify chemical nomenclature, providing a number of new terms, symbols, and approaches to the description of materials. With the advent of atomic theory in the 19th century, new classification schemes based on quantitatively describing the atomic arrangement and composition of minerals were proposed, representing a significant step towards modern mineralogy. Understanding the development of chemical notation over time not only facilitates the identification of mineral specimens, but may also provide clues as to the date that the sample was documented, and potentially even the location.

Introduction

Historical mineral collections, found either in private ownership or as museum acquisitions, may offer a range of curatorial dilemmas, including inappropriately stored specimens (e.g. sulphide corrosion damage), hazardous samples (e.g. radioactive material), and lack of adequate documentation, which may require specimens to be investigated and re-identified. A common feature of such collections, even where documentation is preserved, is a bewildering array of mineral names and chemical notations, many of which will be entirely unknown to the majority of modern day scientists who have no specific interest or prior experience in the historical evolution of chemical language and notation (**Figure 1**). This is further compounded by the relatively rapid progression of chemical language over a period of around 250 years, across a number of European countries, as notable individuals sought to distance what was then modern chemistry from the fantastical shadow of alchemy, each devising their own systems of documenting the natural chemical world whilst potentially rejecting others. However, this apparent problem may be of benefit to those interested in the curation of geological materials, providing a resource which can not only inform efforts to date the collection and assist in the identification of individual specimens, but can also provide useful geographical information on the collections origins, as well as highlighting any potential late additions to a collection that would otherwise be lost to history. As such, a general understanding of how the symbols and terms applied to chemistry have changed throughout history can be of benefit to curators, collectors, and enthusiasts alike.

Early forms of chemical notation

The history of chemical notation begins with the vast field of alchemy, a curious branch of pseudo-science which began in numerous forms (e.g. Western, Indian, Chinese) in the ancient world. Although the aims of alchemy, such as the transmutation of base metals into noble metals, or the creation of an ‘elixir of immortality', are quite rightly recognized by modern scientists as entirely unobtainable and thus dismissed, many of the processes which alchemists employed were themselves quite rational and recognizable to modern chemists. The first attempts to associate names and symbols to natural materials are attributed to alchemy, with some of the earlier examples being traced from their usage in the 18^{th} century back to Egyptian hieroglyphics and other ancient symbols (e.g. Étienne François Geoffroy's table of affinities; **Figure 2**). Nomenclature was based upon physical properties which could be readily tested, such as colour, taste, consistency, crystalline form, solubility, and smell. For example, lead and tin were named by the romans *plumbum candidum* (white lead), and *plumbum nigrum* (black lead), respectively (**Figure 3**). In the 16^{th} century, Georgius Agricola (known as the father of mineralogy) named bismuth *plumbum cinereum* (ash-coloured lead). Throughout the 15^{th} to 18^{th} centuries, this approach led to the use of some names which sound peculiar to modern scientists, such as butter of arsenic ($AsCl_3$), liver of Sulphur (K_2S_x), and sugar of lead (($Pb(C_2H_3CO_2)_2$)), to name a few. It is interesting to note the influence of German miners on modern mineral nomenclature. Some names have endured the test of time such as *blende* which is of Middle High German (1675-1685) origin (**Figure 4a)**. This mineral word is derived from blenden, meaning to make blind or to deceive, a reference to the confusion between zinc and lead sulphide ores. Galena (**Figure 4b**) has a derivation from the 1600's and is a Latin term meaning a mixture of lead and silver together with the dross (waste) from the refining process. Fluorspar (**Figure 4c**) owes its origin to the German word flusspath, referring to its property of acting as a flux. The introduction of these mineral terms can be traced to at least the early years of the Tudor period. Both Henry VIII and Elizabeth I invited German miners and smelters to England to prospect for noble metals, copper, mercury and lead. The exploitation of these minerals would not only provide royalties to the Crown but also ensure a supply of indigenous resources against a backdrop of European political and religious difficulties. German miners together with their families brought expertise, customs, traditions and mining terms to England. Descriptive words for common minerals entered the local mining vernacular, such as the previously mentioned, blende, galena and fluorspar.

Where chemical symbols were used in mineralogy and alchemy, they included both abbreviations (e.g. Copper = ♀, derived from Φ, abbreviated from Φωσφόρος), as well as pictograms which often described the name of a substance rather than the substance itself (e.g. Litharge (lead (II) oxide) = ↑☾, derived from symbols for stone (λίθος) and silver (άργῠρος). The development of these symbols into mineralogy was augmented by religious houses; as with the Schism brought about by Henry VIII and the dissolution of the Catholic monasteries in the U.K., a similar fate befell the monasteries of Germany. In 1773, Pope Clement XIV ordered the dissolution of the Jesuit Order and over the next 30 years, Kings, dukes and noblemen expropriated the wealth of the monasteries. Many monks had a scientific interest in branches of medicine, biology and alchemy. Monasteries had resident libraries and collections of natural history, including minerals from the numerous local mining locations. These collections were distributed by the nobility and some mineral assemblages were incorporated into collections within grammar schools (Lyceum). The specimens were labelled with the alchemical symbols and some of these survivors can be seen in museums today. **Figure 5** shows a specimen of cinnabarite from Wieda, Harz, Germany, as well as some additional examples of specimen labels, which clearly indicate alchemical symbols, including mercury.

By the 18th century, considerable effort was being made by notable chemists and mineralogists such as Torbern Bergman (1735-84), for whom the uranium ore torbernite is named, Antoine Lavoisier (1743-94), Antoine François, comte de Fourcroy (1755-1809), Louis-Bernard Guyton de Morveau (1737-1816), Jean Henri Hassenfratz (1755-1827), and Pierre Adet (1763-1834), to rationalise chemical nomenclature and shake off the terms of the past, linked to similar reforms in the field of botany. This culminated in 1787 with the publication of the "Méthode de nomenclature chimique", a book which was inspired by a memoir introduced to the Académie des Sciences at a public meeting on 18th April 1787 and entitled "On the necessity of reforming and perfecting the nomenclature of chemistry". An English translation of the Méthode was published in London in 1788 but the nomenclature was slow to be adopted. The first full translation was performed by James St John who had studied in Paris and was in contact with the authors of the Méthode. St John had noted the custom in France to change the ph into f in several words of Greek derivation and hence the French sulfur, he thought, should be anglicised to sulphur. He also proposed in 1788 that the French term sulfuré should be translated as sulphuret, a proposal which was accepted and utilised widely (but not exclusively) in a number of mineralogical and chemical articles (e.g. the Philosophical Transactions of the Royal Society of London article by the Count de Bournon, F.R.S.,L.S. entitled "Analysis of a triple sulphuret of lead, antimony and copper, from Cornwall"). As such, specimens labelled with confusing names such as ‘sulphuret of zinc on quartz’ (observed in a boxed collection from the celebrated mineral dealer John Mawe on display in Buxton Museum and Art Gallery), or stalactitic sulphuret of iron (John Lavin, 1840s) became common during this broad time period (**Figure 6**). The decision of other individuals to reject this term further complicates the overall issue of notational diversity. For example, a collection from White Watson of Bakewell dated 1799 entitled "Catalogue of a collection of fossils, the productions of Derbyshire arranged by White Watson F.L.S. makes no mention of sulphurets and the colloquial terms blende, Black Jack, ore of zinc, galena and lead ore are employed instead.

Modernizations of the 19th century

The English chemist, physicist, and meteorologist John Dalton (1766-1844), advocate of atomic theory, made considerable progress in the development of chemical nomenclature by developing a series of symbols which relate directly to a defined quantity of a given element (**Figure 7**). For example, his symbol for carbon (●) represented a single atom, whereas previous symbols were purely qualitative. Furthermore, the decision to assign exclusively circular symbols was a deliberate attempt to depict atoms as he envisaged them. These symbols also facilitated the depiction of molecules in accordance with his ideas on atomic structure (e.g. the formula for carbon dioxide could be given as ‘○●○’). It is noteworthy that half of the 36 symbols he proposed in his 1810 paper incorporated letters rather than simple patterns. Although this is generally believed to reflect the exhaustion of simple shapes and patterns available, it represents a notable step towards modern chemical notation.

During the same time period, the Swedish chemist Jöns Jacob Berzelius (1779-1848) developed his own symbols based on atomic theory, which are more recognizable to modern chemists and mineralogists. In the development of his system, Berzelius was influenced not only by Dalton, but also by Thomas Thomson, a Scottish mineralogist and chemist who, in his 1802 publication entitled 'System of Chemistry' denoted twelve chemical constituents of minerals by their initial letters (e.g. A = alumina, L = lime, P = potash). Thomson constructed formulas by arranging these letters in order of decreasing abundance in the mineral; for example, the formula 'SAWL' was applied to a zeolite mineral determined to contain 53 % silica, 27 % alumina, 10 % water, and 9.5 % lime. This application of letter-based nomenclature was intended to compensate for deficiencies in mineralogical nomenclature, but, through Berzelius, found considerable application in chemistry.

Berzelius published his own symbols in 1813 in a paper entitled 'Experiments on the Nature of Azote, of Hydrogen and of Ammonia and upon the Degrees of Oxidation of which Azote is susceptible' (Azote being an early name for nitrogen). In this paper, he applied a variety of symbols (**Table 1**), stating that "when two bodies have the same initial letter I add the second letter and should that also be the same, I add to the initial the first consonant of the word that differs". As such, magnesium and manganese are distinguished notationally by the symbols Mg and Mn, respectively, as they remain today. Berzelius wrote a further paper in January of 1814 to develop his notation. He explained the choice of initial letter of the Latin name of each element. Also, to denote simple compounds he joined the elementary symbols with a plus sign

$$Cu+O \quad = \quad \text{oxidumcuprosum}$$

$$Cu+{}_2O \quad = \quad \text{oxidumcupricum}$$

$$_2H + O \quad = \quad \text{water}$$

Note the use of subscript integers prior to the element. To denote more complex compounds an index number was placed above any atom of which there was more than one e.g. copper sulphate:

$$CuO + S\overset{3}{O}$$

In another article printed during the same year, Berzelius discussed the development of this theory by now using a superscript against any element to denote the number of atoms. Hence, copper sulphate became:

$$SO^3 + CuO$$

He argued that even this notation could be further abbreviated by a series of dots above the element to show the number of atoms of oxygen associated with it, hence persulphate of copper $_2SO^3 + CuO^2$ became:

$$\dddot{S}^2\ddot{Cu}$$

Berzelius implied that by using these dots he was able to bring his mineralogical and chemical formulae closer together. Examples of this form of notation are given in **Figure 1**, which shows specimen labels from a mineral collection possibly originating from Saxony. By 1818 Berzelius had compiled a table of some 2000 simple and compound substances. At this time he proposed further abbreviations for water of crystallisation and alum now became:

$$\ddot{K}\,\dddot{S}^2 + {}_2\dddot{Al}\,\dddot{S}^3 + 48\ Aq$$

Further changes were made using some symbols such as dashes, commas and crosses for certain compounds but these introduced difficulties and were not universally accepted. This notation made sense out of the chaos that had dogged earlier notation but the adoption of the main principles was not quickly adopted. France, through the leading chemists of the day, adopted the regime in 1824 and chemists in Germany used the symbols from the early 1830's. Changes in all countries were made to simplify nomenclature such as adopting N instead of Az (Azote). The first publication of Berzelius' symbols occurred in a British journal but acceptance of the system was slow to be adopted. By 1833 a number of British chemists had seen the benefits of adopting this method. Turner in his 4th edition of "Elements of Chemistry, 1833" remarked that "the state of chemistry makes their adoption now imperative"

Berzelian Notation and the Arrival of Modern Formulae Representation

The introduction of Berzelian notation began the change from the old chaotic system of representation which still had vestiges of alchemy. Berzelius, taking inspiration from Dalton, introduced his system to show the proportions of chemical composition. His system tried to simplify the formulae by introducing a further notation to show the number of oxygen atoms associated with a particular element as is shown above. Furthermore he was persuaded to develop this system to account for sulphur atoms with a dash and the various arsenic sulphides could be represented by As with the associated sulphur atoms as dashes above, such as Äs. The system became a little more complex as symbols for phosphates, molybdates, vanadates etc were developed. This added further complications and introduced the possibility of errors in reading the formulae and within the printing process. It is difficult to date the transitions of notations but after Berzelius developed his system from 1813 onwards it was adopted within a relatively short period, most chemists realising that chemical formulae became easier to represent and understand under the new regime. It would appear that this notation and the use of superscripts stood the test of time before modern notation became adopted.

Dating the adoption of modern chemical notation

Analysing German and French papers between 1843 and 1874, papers within The Philosophical Magazine between 1845 and 1850, chemistry textbooks from 1836 to 1866 and translated European chemical references between 1855 until 1858 shows that Continental Europe appeared to adopt modern notation in the region of 1865. English publications appear to have transferred to modern notation much earlier, possibly by 1843 (including translations of European chemistry manuals). The disparity between European and English (including American) adoption is puzzling and may have a number of reasons. The transition is not uniform and occasional outliers exist but the trend is definite. No doubt the change is a consequence of editorial policy but what brought about this transformation when European advancement in chemistry was taking place. Berzelian notation had made a considerable advance beyond the previous representations of compounds but it became obvious from an early time that this notation was unsuitable for organic compounds, yet inorganic compound notation resisted the changes for a long period. Whether change came about as a consequence of National or International Congresses on chemical representation requires further investigation. It has been noted that publishers became concerned about the labour-intensive nature of this notation when using dots above the elements and the further complications inherent when using other related notations such as dashes, commas and lines.

One further book needs to be mentioned and that is**:** Manual of the Mineralogy of Great Britain and Ireland published in 1858 and written by Greg and Lettsom. The chemical notation used exclusively in this book is based on Berzelius. There is extensive use of dots to represent oxygen in the chemical formulae, and dashes to represent sulphur (**Table 2**). Note that in this notational scheme, the presence of two atoms of the same element was indicated with a strike-through, as shown for chalcopyrite.

Changes in notation may have been gradual or precipitous and requires more investigation of the archives to determine whether this might have been the case. Even though the English publications appear to adopt the modern notation by 1843 it is interesting to note that the book by Greg and Lettsom in 1858, which is a major advance in the study and science of mineralogy retains the old notation completely. Indeed, throughout the book the formulae used the dot for oxygen and the dashes for the presence of sulphur. So, why is such an authoritative book using old notation? Could it be that the book was such a major work that it was a long time in preparation before eventual publication and was too late for revision? Nevertheless, it was probably published in the sure knowledge that readers would still be familiar with an older notation and understood by the scientific community. It is interesting to note that in German mineralogy books the same trend exists in the later adoption of modern notation. Berzelius notation was used by Quenstedt: "Handbuch der Mineralogie" 1863, Blum: "Lehrbuch der Mineralogie" 1874, but not by Leunis, Senft: "Synopsis der Mineralogie und Geognosie 1875.

Summary

Historical mineral collections frequently offer a veritable treasure trove not only of geological materials, but also valuable historical information, preserved in the form of chemical notation on sample labels. Preserved, original specimen labels may yield curious symbols, words, and codes intended to classify the sample, based upon the knowledge and the language of the time (**Table 3**). Many of these symbols and notational schemes date back hundreds (or thousands!) of years in their origin, and are largely unrecognisable to modern scientists. However, they may also offer fascinating insight into the history of an individual sample, facilitating its identification, and the reconstruction of when, and perhaps where, the specimen was collected. It is curious that despite having embraced modern chemical terms, those from a bygone age still endure.


13
Praseolite
Hungary
14.
Schwarzenberg
Saxony
Diadochite
Saalfeld
Turingia
155.
Epidote
Lime-Iron-Epidote
Dauphiny
France

Figure 1

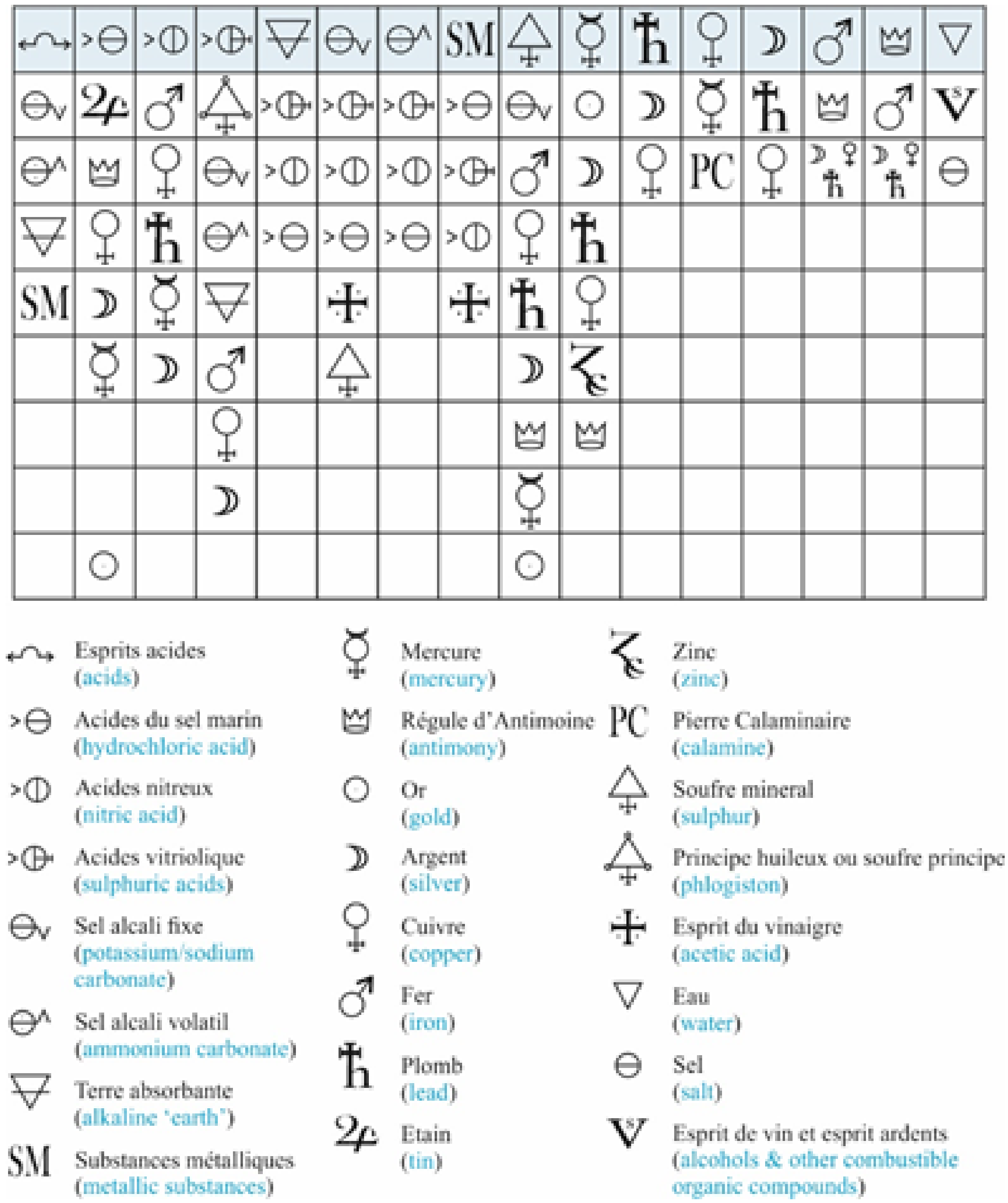

SM
PC
Esprits acides (acids)
Acides du sel marin (hydrochloric acid)
Acides nitreux (nitric acid)
Acides vitriolique (sulphuric acids)
Sel alcali fixe (potassium/sodium carbonate)
Sel alcali volatil (ammonium carbonate)
Terre absorbante (alkaline 'earth')
SM Substances métalliques (metallic substances)
Mercure (mercury)
Régule d'Antimoine (antimony)
Or (gold)
Argent (silver)
Cuivre (copper)
Fer (iron)
Plomb (lead)
Etain (tin)
Zinc (zinc)
PC Pierre Calaminaire (calamine)
Soufre mineral (sulphur)
Principe huileux ou soufre principe (phlogiston)
Esprit du vinaigre (acetic acid)
Eau (water)
Sel (salt)
Esprit de vin et esprit ardents (alcohols & other combustible organic compounds)

Figure 2

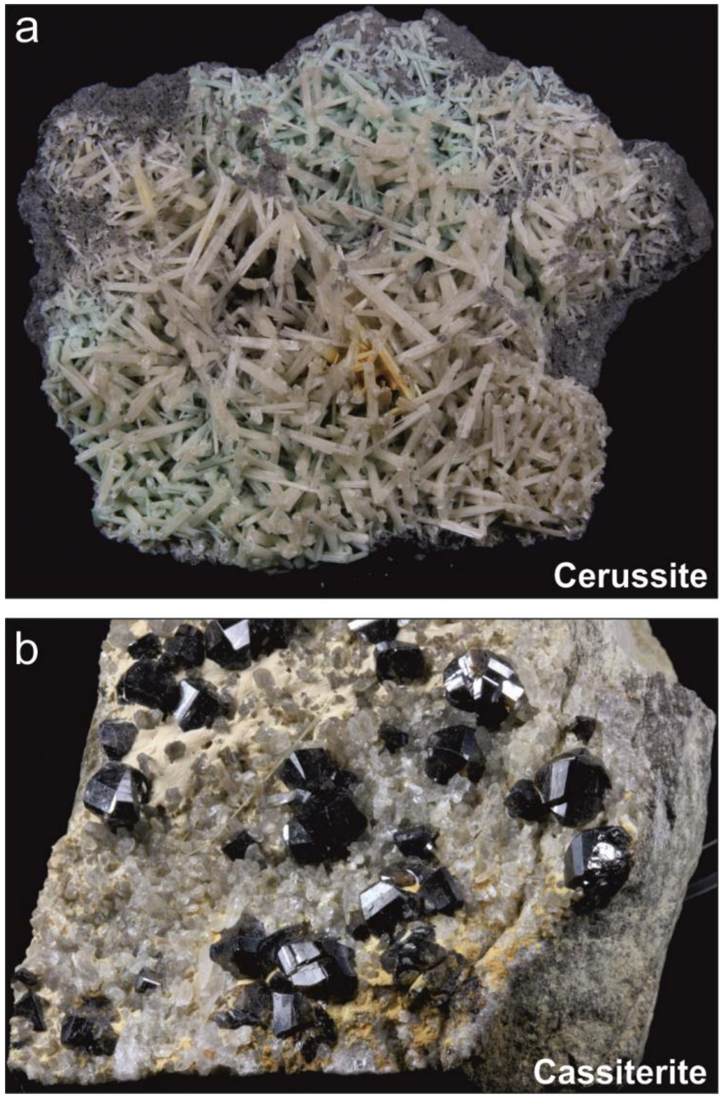


Figure 3


a
Blende Sphalerite
Barrow mine nr Keswick
b
Galena
Millclose Mine, Derbyshire
c
Fluorspar
Treak Cliff
Castleton

Figure 4

Figure 5

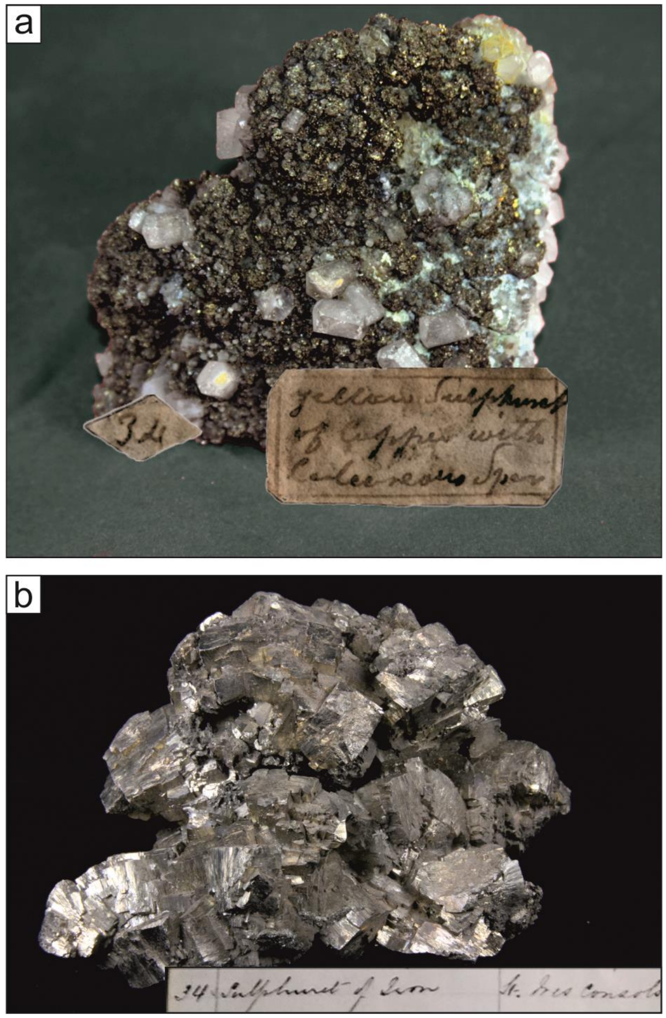

a
34
yellow Sulphuret of Copper with Calcareous Spar
b
34
Sulphuret of Iron

Figure 6

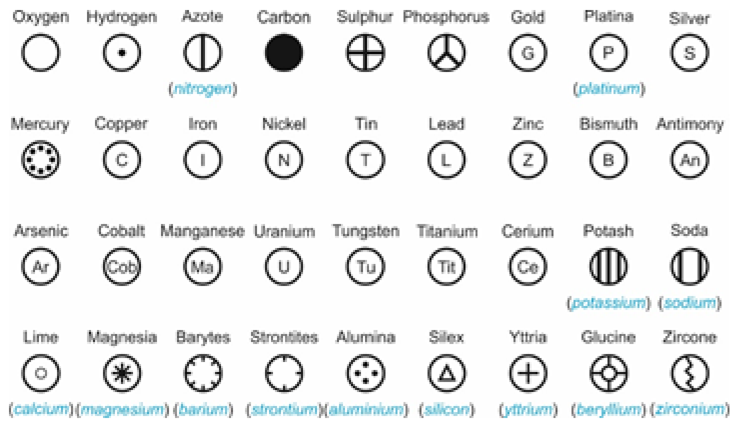

Oxygen
Hydrogen
Azote
Carbon
Sulphur
Phosphorus
Gold
Platina
Silver
(nitrogen)
(platinum)
Mercury
Copper
Iron
Nickel
Tin
Lead
Zinc
Bismuth
Antimony
Arsenic
Cobalt
Manganese
Uranium
Tungsten
Titanium
Cerium
Potash
Soda
(potassium)
(sodium)
Lime
Magnesia
Barytes
Strontites
Alumina
Silex
Yttria
Glucine
Zircone
(calcium)
(magnesium)
(barium)
(strontium)
(aluminium)
(silicon)
(yttrium)
(beryllium)
(zirconium)

Figure 7

Figure captions

Figure 1: Examples of a collection of geological specimens possibly derived from Saxony. The collection includes examples of original labels which illustrate varying degrees of damage and deterioration. The examples given of praseolite (specimen presumed to be a variety of cordierite), scorodite ($FeAsO_4 \cdot 2H_2O$), diadochite ($Fe^{3+}_2(PO_4)(SO_4)(OH) \cdot 5H_2O$), and epidote ($Ca_2Al_2(Fe^{3+};Al)(SiO_4)(Si_2O_7)O(OH)$), demonstrate the difficulties associated with defunct chemical notation.

Figure 2: Geoffroy's Table of Affinities, originally published in 1782. A variety of chemical substances are included, each with their own given alchemical symbol, many of which have origins in antiquity. For example, the symbols for gold and silver relate to the sun and the moon, respectively, and are based on the colours associated with each metal.

Figure 3: Examples of minerals with original names describing their colour. **a)** Cerussite ($PbCO_3$), originally named Plumbum Candidum or 'White lead). **b)** Cassiterite (SnO_2), originally named Plumbum Nigrum or 'Black lead'.

Figure 4: Examples of minerals which have retained their historical trivial names. **a)** Blende (modern name: sphalerite) from the Middle High German *blenden*, meaning to deceive or blind **b)** Galena, derived from the Latin for a mixture of lead, silver, and the dross (waste) from the refining process **c)** Fluorspar (modern name: fluorite) from the German *Flusspath*, meaning to flow.

Figure 5: Examples of mineral specimen labels with alchemical symbols (images used courtesy of Prof. J. Dietrichs) **a)** a specimen of cinnabarite with **b)** corresponding label bearing the alchemical symbol for

mercury **c)** original label for a specimen of cinnabarite housed in Tayler's Museum, Haarlem which shows the alchemical symbol for mercury **d)** a range of mineral specimen labels which display various alchemical symbols, including tin, copper, and iron.

Figure 6: Examples of the usage of the term *sulphuret* **a)** a chalcopyrite specimen from the Ecton copper mines of Staffordshire incorrectly labelled as sulphuret of copper **b)** a pyrite specimen from Cornwall labelled as sulphuret of iron.

Figure 7: The chemical naming scheme devised by John Dalton (1766-1844), in which each symbol can be related to a given quantity of a chemical substance.

Chemical element	**Berzelian symbol**	**Original name (where applicable)**
Nitrogen	Az	Azote
Oxygen	O	
Lead	P	Plumbum
Sulphur	S	
Tin	Sn	Stannum
Chlorine	M	Muriaticum
Magnesium	Mg	
Manganese	Mn	

Table 1

Symbols proposed by Berzelius in his 1813 paper entitled ‘Experiments on the Nature of Azote, of Hydrogen and of Ammonia and upon the Degrees of Oxidation of which Azote is susceptible’

Mineral group	Example mineral	Greg and Lettsom's Berzelian notation	Modern notation
Sulphate	Anglesite	$\dot{\mathrm{Pb}}\,\dddot{\mathrm{S}}$	$PbSO_4$
Carbonate	Dolomite	$\dot{\mathrm{Ca}}\,\ddot{\mathrm{C}} + \dot{\mathrm{Mg}}\,\ddot{\mathrm{C}}$	$CaMg(CO_3)_2$
Oxide	Cassiterite	$\ddot{\mathrm{Sn}}$	SnO_2
Sulphide	Chalcopyrite	$\overset{\prime}{\mathrm{Cu}}\,\overset{\prime\prime\prime}{\mathrm{Fe}}$	$Cu_2Fe_2S_4$

Table 2

Berzelian notation used extensively by Greg and Lettsom

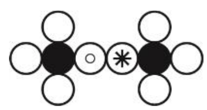
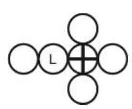
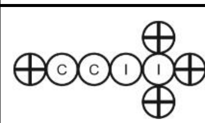
Mineral	Alternative name(s)	Alchemical notation	Dalton's notation	Thompson's notation	Greg and Lettsom's Berzelian notation	Modern notation
Iron pyrite	Sulpheret of iron	♂		SI	$\overset{\prime\prime}{Fe}$	FeS_2
Cinnabarite	Sulpheret of mercury	☿		MS	$\overset{\prime}{Hg}$	HgS
Dolomite				LMCO	$\dot{Ca}\,\ddot{C} + \dot{Mg}\,\ddot{C}$	$CaMg(CO_3)_2$
Sphalerite	Zinc blende or Sulpheret of zinc			ZIS	$\overset{\prime}{Zn}$	(Zn,Fe)S
Cassiterite		♃		TO	$\ddot{Sn}$	SnO_2
Anglesite		♄		LOS	$\dot{Pb}\,\dddot{S}$	$PbSO_4$
Chalcopyrite		♂♀		CSI	$\overset{\prime}{\not{Cu}}\,\overset{\prime\prime\prime}{\not{Fe}}$	$Cu_2Fe_2S_4$

Table 3

Summary table highlighting the variety of chemical notation schemes employed by alchemists, mineralogists, and chemists. It should be noted that the schemes described here lack the standardisation of modern chemistry and are subject to considerable interpretation by the user. As such, the examples given do not represent a single and definitive form of notation for a given mineral.