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The St Andrews Periodic Table Wallchart and its Use in Teaching

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Abstract. An early surviving copy of a periodic table of the elements wallchart is described and it is compared with other early versions of the periodic table. The status of chemistry teaching in St Andrews at the time and particularly the lectures of Professor Thomas Purdie are considered to show the context in which this periodic table would have been used and gain some appreciation of it pedagogical importance.

Keywords. Periodic table wallcharts, Thomas Purdie, teaching tools.

INTRODUCTION

In June 2014 an old periodic table wallchart was discovered in the course of clearing out a storage space at the University of St Andrews. Based on the absence of the element germanium (discovered 1886), it could be dated to the 1880's and a subsequent investigation showed that it was produced in Vienna in 1885 and ordered for delivery to St Andrews by the newly appointed Professor Thomas Purdie from the scientific supply company C. Gerhardt of Bonn in October 1888.[1] In this article we describe in detail the features of this historic periodic table and how it relates both to other early periodic table wallcharts, and to the teaching of chemistry in St Andrews at that time.

Very fortunately, meticulous notes made by Professor Purdie have been preserved in the University of St Andrews Library. These report several instances of his teaching such things as atomicity (valency) and periodicity. In his lectures he refers to the periodic system of classification of the elements and mentions the discoveries made with the aid of the periodic law, in particular the correction of atomic weights and the discovery of new elements.

The wallchart also presents chalk markings recording some of the new elements such as the noble gases, which with the exception of helium (first recognised in the sun in 1868) were discovered in the 1890s. This interaction with the wallchart gives a remarkable insight into the teaching of chemistry in the late 19th century.

THE ST ANDREWS TABLE

The St Andrews periodic table was printed on canvas-backed paper and was found rolled up with a wooden hanging baton at the top (Figure 1).[2] Its size is approximately 115 × 85 cm and the layout closely follows Mendeleev's second Table of 1871 (Figure 2).[3] In this the known elements are arranged vertically in groups according to their properties and in particular the formula of their oxides and/or hydrides, and then horizontally according to increasing atomic weight. The title is in German and the table was produced in Vienna, at that time part of the Austro-Hungarian Empire. At the bottom left the publisher is identified: "Verlag v. Lenoir & Forster, Wien", while at the bottom right the printer is named: "Lith. v. Ant. Hartinger & Sohn, Wien". The publisher George André Lenoir (1825–1909) studied chemistry and physics in his native Kassel and in Paris and settled in Vienna in the 1850's where he established a scientific instrument factory as well as a publishing house, later run in partnership with Forster. [4] Originally based at Magdalenenstrasse 14, the business moved in 1888 to Waagasse 5 in Vienna's 4th district. Anton Hartinger (1806–1890) was a Viennese artist and lithographer who specialised in flower painting and was a pioneer of chromolithography.

Although the presence and absence of certain elements allows us to date the table to the time period 1879–1886, more definitive evidence for its precise date of publication was obtained by researching historical documents. In his definitive listing of historical chemistry resources,[5] H. C. Bolton (1843–1903) lists an item "Wandtafel der Periodische Gesetzmässigkeit der Elemente nach Mendelejeff. Wien, 1885." whose title corresponds exactly to that of the St Andrews table and with a date in the right range. However this gave no indication of the publisher or suppliers and to make further progress we had to check the university accounts and records from that time. In the archives of the University of St Andrews an invoice was discovered dated 16th October 1888 from C. Gerhardt (Bonn) to "United College, St Andrews, Scotland", accompanied by a receipt addressed to Professor Thomas Purdie, with an item:[6]

2359 1 Wandtafel von Mendelejeff 3.–

After some effort a copy of the catalogue of C. Gerhardt (7th edition, 1885) was located at the National

Periodische Gesetzmässigkeit der Elemente nach Mendelejeff.

Reihen	Gruppe I R^2O	Gruppe II RO	Gruppe III R^2O^3	Gruppe IV RH^4 RO^2	Gruppe V RH^3 R^2O^5	Gruppe VI RH^2 RO^3	Gruppe VII RH R^2O^7	Gruppe VIII RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	Sc=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59 Ni=59, Cu=63
5	(Cu=63)	Zn=65	Ga=68	-=72	As=75	Se=79	Br=80	
6	Rb=85	Sr=87	Yt=88	Zr=90	Nb=94	Mo=96	-=100	Ru=104, Rh=104 Pd=106, Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	Ce=137	La=139	-	Di=145?	-	- - - -
9	(-)	-	-	-	-	-	-	
10	- 165	- 169	Er=170	-173	Ta=182	W=184	-	Pt=194, Os=195(?) Ir=193, Au=196
11	(Au=196)	Hg=200	Tl=204	Pb=208	Bi=210	-	-	
12	-	-	-	Th=231	-	U=240	-	- - - -

Figure 1. The St Andrews Periodic Table Wallchart as discovered. R. Alan Aitken, 2014.

Museum of Natural History and Science, University of Lisbon, and in this the following entry appears:

2359 Periodische Gesetzmässigkeit der Elemente nach Mendelejeff. Wandtafel von 116 × 87 Mark 3.–[7]

This then provided clear evidence that our table was printed in Vienna in 1885 and ordered for delivery to St Andrews in October 1888.

Interestingly, the immediately preceding item on the invoice:[7]

2358 Wandtafeln von 1–5 Lieferung I 6.–

as well as the corresponding entries on a later invoice of 11th January 1889

2358 Wandtafeln von 6-10 Lieferung II 6.–
" " 11-15 " III 6.–

could be identified as the series of 15 chemistry wallcharts produced by Dr Georg v. Schroeder (1843–1895) and Dr Julius v. Schroeder (1808–1888) of which number 3 showing the production of nitric acid ("Taf. III saltpetersaüre fabrikation") has also survived and was discovered in the same store-room along with the periodic table. These charts with the series title "Tafeln für den Unterricht in der allgemeinen Chemie und chemischen Technologie" also date from 1885 and were printed and published by Theodor Fischer in Kassel.[8] It is clear that the periodic table wallchart was by no means a unique item, but rather one of many such wallcharts that were ordered up and used routinely in teaching chemistry in St Andrews in the 1880's.

In view of its importance, plans were made to restore and conserve the table and this work was carried out between November 2017 and May 2018 by conservator Richard Hawkes at Artworks Conservation in Harrogate. First the paper was surface cleaned using a brush to remove loose surface dirt and debris. The canvas backing was peeled away gradually, scraping away the adhesive (flour paste) after swelling with methyl cellulose. To remove the soluble discolouration and some of the acidity, the paper was washed in de-ionised water adjusted to a neutral pH with calcium hydroxide. The paper was de-acidified and left with an alkaline reserve to counter future acidity by immersing in a bath of 0.1M magnesium hydrogen carbonate (pH 6.5). Strips of strong and long fibered Japanese paper derived from the kozo plant, were applied with wheat starch paste to repair tears and losses. The restored original is now housed in conservation grade material and is stored in Special Collections' climate-controlled stores in the University. A full-size facsimile is now on display in the School of Chemistry (Figure 3).

OTHER EARLY PRINTED WALL CHART TABLES

The most closely similar periodic table wallchart to the St Andrews table of which we are aware is one housed at Kyoto University Library, Japan and dated 1893 (Figure 4). This is also published by Lenoir & Forster, but from their later (post 1888) Waaggasse address and, following Hartinger's death in 1890, we have a new lithographer "Lith. v. Guberner & Hierhammer Wien, IV. Hptst. 51." The layout is essentially identical but crucially germanium (discovered 1886[9]) is now present, the posi-

Reihen	Gruppe I. — R^2O	Gruppe II. — RO	Gruppe III. — R^2O^3	Gruppe IV. RH^4 RO^2	Gruppe V. RH^3 R^2O^5	Gruppe VI. RH^2 RO^3	Gruppe VII. RH R^2O^7	Gruppe VIII. — RO^4
1	H=1							
2	Li=7	Be=9,4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27,3	Si=28	P=31	S=32	Cl=35,5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59, Ni=59, Cu=63.
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	?Yt=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104, Pd=106, Ag=108.
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	J=127	
8	Cs=133	Ba=137	?Di=138	?Ce=140	—	—	—	— — — —
9	(—)	—	—	—	—	—	—	
10	—	—	?Er=178	?La=180	Ta=182	W=184	—	Os=195, Ir=197, Pt=198, Au=199.
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	—	—	
12	—	—	—	Th=231	—	U=240	—	— — — —

Figure 2. Mendeleev's second Table of 1871 taken from ref. 3 (p. 151).

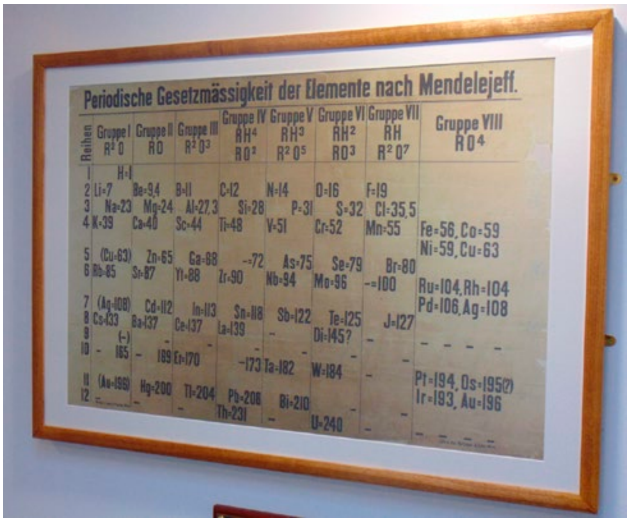

Figure 3. Facsimile of the St Andrews Table on display following conservation. University of St Andrews School of Chemistry. R. Alan Aitken, 2018.

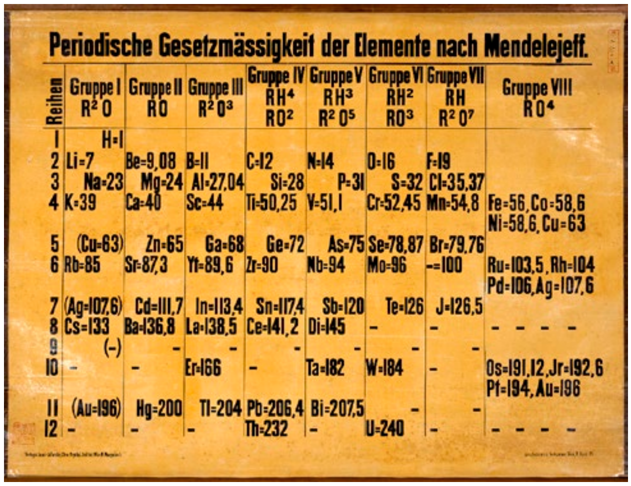

Figure 4. Kyoto University periodic table, 1893. Kyoto University Rare Materials Digital Archive (https://rmda.kulib.kyoto-u.ac.jp/en/item/rb00024049)

tions of lanthanum and cerium have been interchanged, and many of the atomic weights are given with greater precision. The same basic layout was retained well into the 20th century and in the N. D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, Moscow, there is a large table following this original Mendeleev layout and going up as far as the element Mendelevium which was discovered only in 1955 (Figure 5).

A US table of intermediate age but retaining many of the features of the 19th century versions (Figure 6) was brought to our attention recently as a result of the publicity surrounding the St Andrews table.[10] This hangs in the Chemistry Department of the University of Northern Iowa, and probably dates from around 1910. All the inert gases are present as well as radium (discovered 1898) but not radon, actinium or lutetium. This table was supplied by the Eimer and Amend company.

Figure 5. Table in the N.D. Zelinsky Institute of Organic Chemistry, Russian Academy of Sciences, Moscow. R. Alan Aitken, 2008.

Finally, we would like to mention a second, later, St Andrews table which nonetheless shows some interesting features (Figure 7). This is marked faintly in the bottom right corner "A. Gallenkamp & Co. Ltd., London" and probably dates after 1925 and before 1931 since hafnium (discovered 1922) is present but francium (discovered 1939) is not. In contrast to all the other tables mentioned here, this has names of elements written out in full rather than symbols. Less familiar names are used for several elements with columbium for niobium, celtium given as an alternative for hafnium, and brevium for protoactinium. An interesting case is masurium, which was announced along with rhenium by Noddack, Tacke and Berg in 1925 but was never isolated, as the element 43 was finally obtained in 1937 by bombarding molybdenum with deuterons and was named technetium.[11] It is also notable that rhenium (isolated in1925) appears but does not yet have an atomic weight value, the first measure of its atomic weight was done in 1928 and in 1931 IUPAC gave its first recommended value.[12] By this time the structure of the table was much better established and the few remaining gaps corresponded to confidently predicted elements that would soon be isolated such as francium (1939), astatine (1940) and promethium (1945).

These are probably but a few examples of what still exists. The celebration in 2019 of the International Year of the Periodic Table of Chemical Elements has possibly led to the discovery or the resurfacing of old tables that, as in the case of St Andrews, have been put out of sight or mind for a number of years.

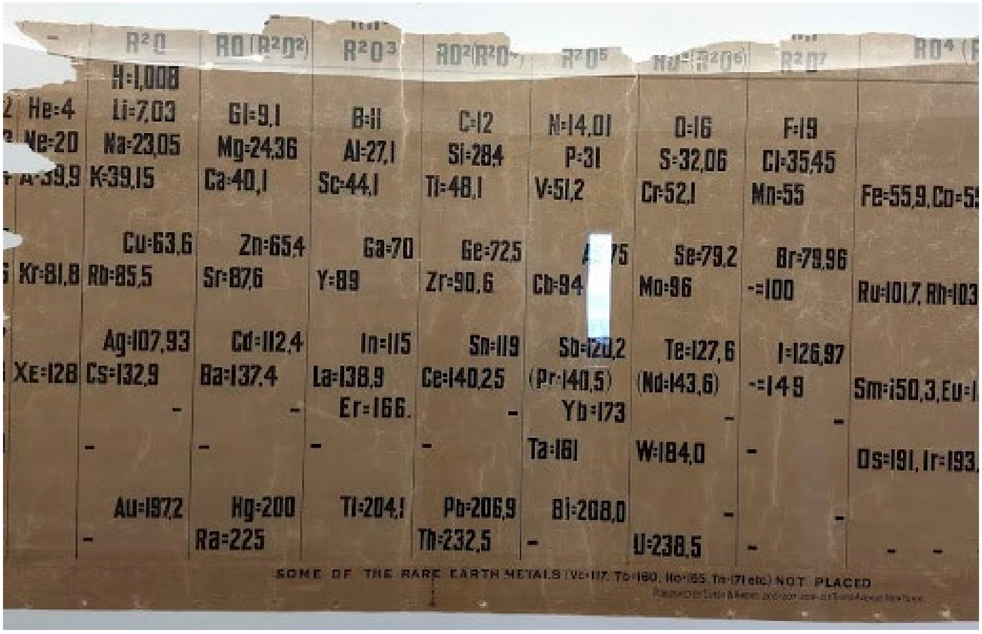

Figure 6. Table at the Department of Chemistry and Biochemistry, University of Northern Iowa, Cedar Falls. Courtesy of Laura Hoistad Strauss.

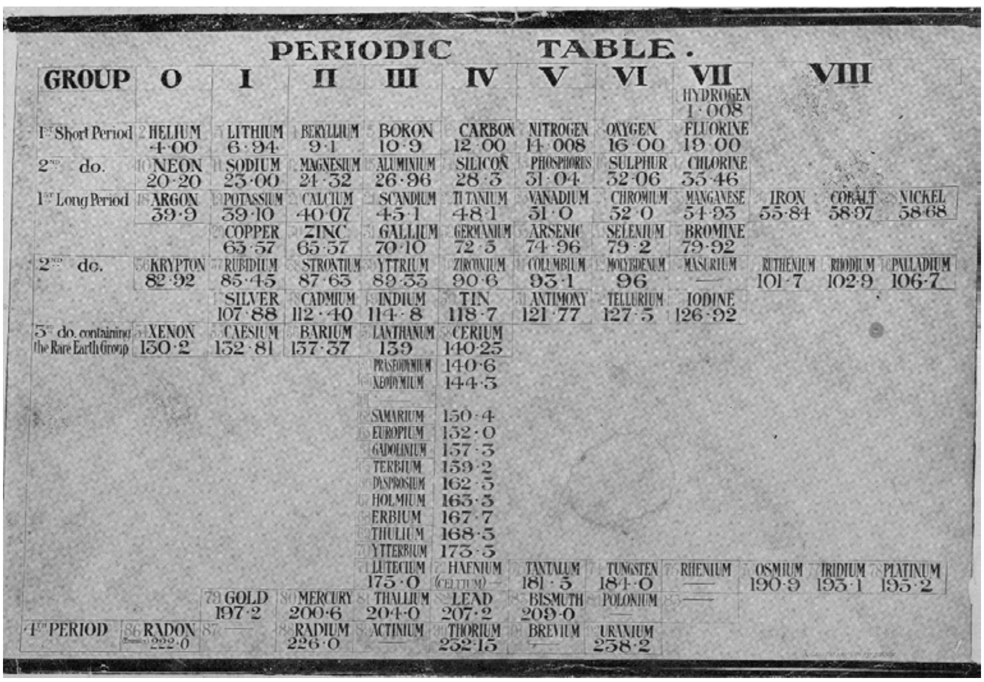

Figure 7. A later periodic table found at the University of St Andrews dating from the 1920's or 1930's. Courtesy of the University of St Andrews Library: ms38515/5/129/6.

THE PEDAGOGICAL USE OF EDUCATIONAL WALLCHARTS

In 1878 Professor Rudolf von Wagner, the Chair of Technology at the University of Würzburg, where Thomas Purdie received a doctorate in chemistry, wrote an article about the use of wallcharts in technological education.[12] In this communication von Wagner notes that in most educational institutions the available resources were insufficient and out of line with the essential equipment for teaching. The docents' ingenuity tried to meet this need delivering demonstrations by means of illustrations. This was the case for Professor Friedrich Knapp in Munich who conceived the idea of producing technological wall charts on a very large scale; his charts were a great success and made an important contribution to the teaching of technology. However, in an area subjected to constant change and improvement, von Wagner claims the need for new charts covering the newest chemical principles as well as the supply of new editions and of revisions of the existing charts.

In his article, von Wagner praises the initiative of the firm Lenoir and Forster in publishing new wallcharts, commenting on their wide distribution and on the high recognition and honours that, for this reason, the company received at the 1878 World Fair in Paris. von Wagner concluded his article mentioning the invaluable aid that photolithographic reproductions of the charts provided for educational purposes.

The didactic mission of Lenoir & Forster was engrained in the history of the company. Originally dedicated to the manufacture of chemical and pharmaceutical devices, the firm was also a successful publishing business, which, among other things, published a celebrated collection of natural science lithographs. Over time the company abandoned the production of chemistry equipment to focus on the distribution of teaching materials of all kinds and, according to the firm's advertisements that have survived, the company aimed "to procure all teaching materials from the whole field of natural sciences, especially chemistry, physics and natural history, as well as to set up chemical factories and metallurgical laboratories".[13]

One can speculate that a firm committed to providing teaching aids and with experience in publishing technological wallcharts as von Wagner refers to in his article, would feel inclined to produce high quality prints of a periodic table of the elements that, until that moment, had been confined to books and articles and had not generally made its way to the walls of the classrooms or laboratories. Lenoir & Forster were most probably pioneers in the mass production of periodic table wallcharts since in the H. C. Bolton compendium mentioned earlier, which exhaustively lists chemical related material published between 1492 and 1892,[5] there is only one entry for a periodic table wallchart and this corresponds to the one produced in Vienna in 1885 by Lenoir & Forster.

The tables were soon distributed by the firm C. Gerhardt in Bonn, being advertised in the catalogue of the company, written in German, and published in Bonn in 1888. Interestingly, the firm issued a catalogue in 1889 published in Bonn with the price in Marks, but written in English and aimed at the American market, that also contained the entry for the periodic table.[14] The earliest US catalogues selling periodic table wallcharts were published in New York in 1895 for the firm C. Gerhardt, in 1896 for Richards & Co. Ltd.[15] and in 1902 for Eimer & Amend. [16] By 1898 Gerhardt's catalogues ceased to advertise the periodic table wallchart.

PURDIE'S TEACHING OF CHEMISTRY

Thomas Purdie FRS (1843-1916) was born in Biggar in southern Scotland and attended Edinburgh Academy. As a young man he spent a period in South America as a cattle rancher but in the 1870's he returned and studied chemistry briefly in St Andrews before transferring to the Royal School of Mines (today's Imperial College, London) to study with Sir Edward Frankland (1825–1899) where he completed a B.Sc. in 3 years. He then went to Germany to work with Wislicenus (1835–1902) in Würzburg, completing his doctorate in 1881. After acting as interim in St Andrews during the absence of Professor Matthew Heddle (1828–1897) in 1882 and 1883, Purdie was elected to fill the chair of chemistry in 1884 and held the position until 1909. He was elected a Fellow of the Royal Society in 1895. As a researcher, Purdie made highly significant contributions to the study of stereochemistry of simple organic compounds and was the first person to resolve lactic acid.[17] He is perhaps best known, however, for developing the Purdie-Irvine method for methylation of hydroxyl groups (silver oxide and methyl iodide)[18] which played a key role in elucidating the structure of simple sugars and underpinned the development of a world-class school of carbohydrate chemistry in St Andrews in the early 20th century.

When he took up the chair he found the department poorly equipped, for the subject did not form part of a definite science curriculum and was instead loosely attached to the Faculty of Arts. In the late 19th century most students at the University took a Master of Arts degree and even the few who went on to complete a Bachelor of Science has usually done an M.A. first. The first Ph.D. degrees were not awarded until 1920.

To quote from his obituary: [19]

The situation offered few prospects for conducting research, and none whatsoever for inducing students to undertake original work in chemistry. Yet, in his introductory lecture, speaking to an audience consisting almost entirely of arts students, we find the new professor unfolding his plans: "I venture to hope," he said, "that I may soon have some students who will be willing to give the time required for original investigation, and I can promise them that, whether the results they may obtain be of scientific value or not, they themselves will be amply rewarded; for, among all the methods of scientific training, there is none of such high educational value as research." "Might it not be possible to remain at St. Andrews during the summer months and undertake some original investigation, the results being published, as is frequently done in Germany, in the joint names of professor and student, and as contributions from the United College, St. Andrews? A beginning once made, a little band of workers would soon collect.

The obituary was written by his successor in the chair of chemistry and most brilliant pupil, James C. Irvine (1877–1952) who regarded Purdie as a "father figure". Indeed, in Irvine's own obituary,[20] we get an insight into the powerful influence that Purdie had on the future direction of chemistry teaching in St Andrews:

It was Purdie who gave him [Irvine] the first vision of the true function of a university science department, in which teaching must be linked with an active prosecution of research.

Back to Irvine's words:[19]

His zeal for research, however, was not allowed to interfere in any way with the conscientious performance of what he felt to be his first duty – the teaching of undergraduates. The policy was sound, for he won students to research by the attraction of his teaching and by his sincere and unaffected interest in their welfare. The class could not fail to be impressed with the fact that the professor enjoyed his lectures, and some share of his keen enthusiasm for the subject inevitably found its way to the occupants of the benches. He spoke with easy, natural fluency, and the few scraps of notes which he faithfully arranged before beginning were soon pushed aside and forgotten.
Naturally enough, it was in the small Honours (senior level) classes that Purdie's gifts as a teacher were best appreciated. Here he abandoned the formal lecture to which the Scottish student has been long accustomed, and the discourse often resolved itself into an informal discussion.

The facilities were initially primitive with a single lecture room and one small laboratory which had to be used for both teaching and research, with the latter only able to begin once the day's classes were over and the materials had been cleared away. The situation improved in 1891 when a new laboratory was added thanks to a donation in memory of Purdie's uncle and just over a decade later, with the increased research activity having already outgrown the previous facilities, Purdie himself financed the construction of a new large building for teaching and research which was completed in 1905. This was the first such dedicated chemical research institute in Scotland and the building survives up to the present time, currently housing the University's Schools of Geography and Sustainable Development and Earth and Environmental Sciences. In 1905 there were eighteen graduate researchers and, within the next few years, the carbohydrate research school in St Andrews became world famous. An early photograph of the research laboratory within the new building (Figure 8) shows such innovative features as an electric light above each bench (at the time the "elementary" or undergraduate lab still had gas lights) and fume cupboards against the back wall.

To Purdie's left is a young James Irvine and the presence of a female chemist is significant. In fact St Andrews was one of the first UK universities to admit women with the first female student, Agnes Forbes Blackadder (1875-1964), graduating in March 1895. In chemistry the first female student was Agnes Marion Moodie (1881-1969) who graduated in 1904 having completed the degree of M.A. in 1902 and B.Sc. in 1903.[21]

Figure 8. The new chemical research laboratory in St Andrews around 1906. Professor Thomas Purdie is the figure in the black coat. Courtesy of the University of St Andrews Library: ID: 2012-12-16.

Significantly the first Ph.D. degrees in the University were awarded to two female chemists, Grace Cumming Leitch (1889-1942)[22] and Ettie Stewart Steele (1891?-1983) who graduated together in July 1920.

INTERACTING WITH THE PERIODIC WALL CHART IN THE CLASSROOM

Having given some impression of the general conditions in the University of St Andrews and the Department of Chemistry around 1888 when the periodic table and other teaching wallcharts were delivered, it is of interest to examine in more detail the precise teaching methods employed and how the chart would fit in with these. Fortunately, Purdie kept meticulous notes which have been carefully preserved.[23] In his own handwriting we have details of what was covered in each daily 50-minute lecture, how it was received by students, which lecture demonstrations did and did not work well and how things could be improved. The first notebook covers the session 1889-90 and the series continues with notes for each academic year until 1903. The annotations on the notebooks are copious and detailed for the first sessions, becoming more succinct over the years. Some illustrative examples follow.

About a lecture given on Wednesday 12th of March 1890, Purdie wrote (Figure 9a):

Lecture LXXX. Wednesday 12th March
Relations of the Atomic Weights to each other.
Prouts Hypothesis.
Relations of the properties of Elements to their Atomic Weights.
Discoveries of Dumas n
Newlands Law of Octaves.
The Periodic Law (Mendelejeff)
Statement of.
Meaning of the term periodic

The lecture was fairly interesting. Attention was taken up with thermochem. phenomena. The description of Mendeleffs table might perhaps be touched on, but it is better I take that along with its practical applications which form an appropriate ending. The above ought not to take more than half a lecture.
Details regarding Mendeleff in Nature *June 27 1889, p. 193.*[26]

It is of interest to notice the different spellings of Mendeleev's name in Purdie's notes. In this lecture, when Purdie mentions the periodic law he spells the name in the customary German form at the time, with the same spelling that appears in the title of the periodic table. The other instances where Purdie writes the name he misses a syllable.

In this lecture's notes Purdie mentions Prout, Dumas, Newlands and Mendeleev. Both Prout's and Dumas's work made significant advances on measuring the atomic weights of the elements.[24] Newlands, for his part, had ordered the elements according to their atomic weights noticing that every eighth element in this system shared similarities. He postulated this *Law of Octaves* in 1865 and received the Davy medal in 1887, being recognized in the U.K. as one of the founders of the periodic system.[25]

Purdie explains Mendeleev's periodic law in this lecture but postpones the description of the periodic table to further lectures when talking about its practical applications. To portray Mendeleev's work, Purdie relies on Sir Edwards Thorpe's recent study on Mendeleev that had appeared in the series Scientific Worthies published in Nature in 1889.[26]

In the next lecture, Purdie continues his notes on the periodic system: (Figure 9b (recto) and 9c (verso)):

Lecture LXXXI. Friday 14th March.
Periodic System of Classification of the Elements.
Series 2. & 3.
Relations of the two series to each other.
Relations of the members of each one of the series to each other in respect of (a) General chemical character (b) <u>oxygen</u> or <u>hydrogen</u> <u>valence</u> (c) physical properties.
meaning of the term short period

Series 4 & 5, & 6 & 7. Considered in same order
Meaning of the term long period

Practical applications
Correction of atomic weights.
Discovery of new elements.

The lecture excited much interest, and was attentive -ly listened to
The description of the table of classification requires to be done more carefully; especially the double periodicity; perhaps the table given in Richter

In which the long periods are given in one line might help.
Physical. Properties. Atomic vol. for the sodium series was given; other properties only alluded to.
As examples of atomic wt. determination Indium + Uranium were given, and for discovery of elements, Germanium (see Richter appendix[27]). Mendeeleff's prediction of dvi tellurium was also put down on board (see Chem Jour. 1889. Trans. 649)

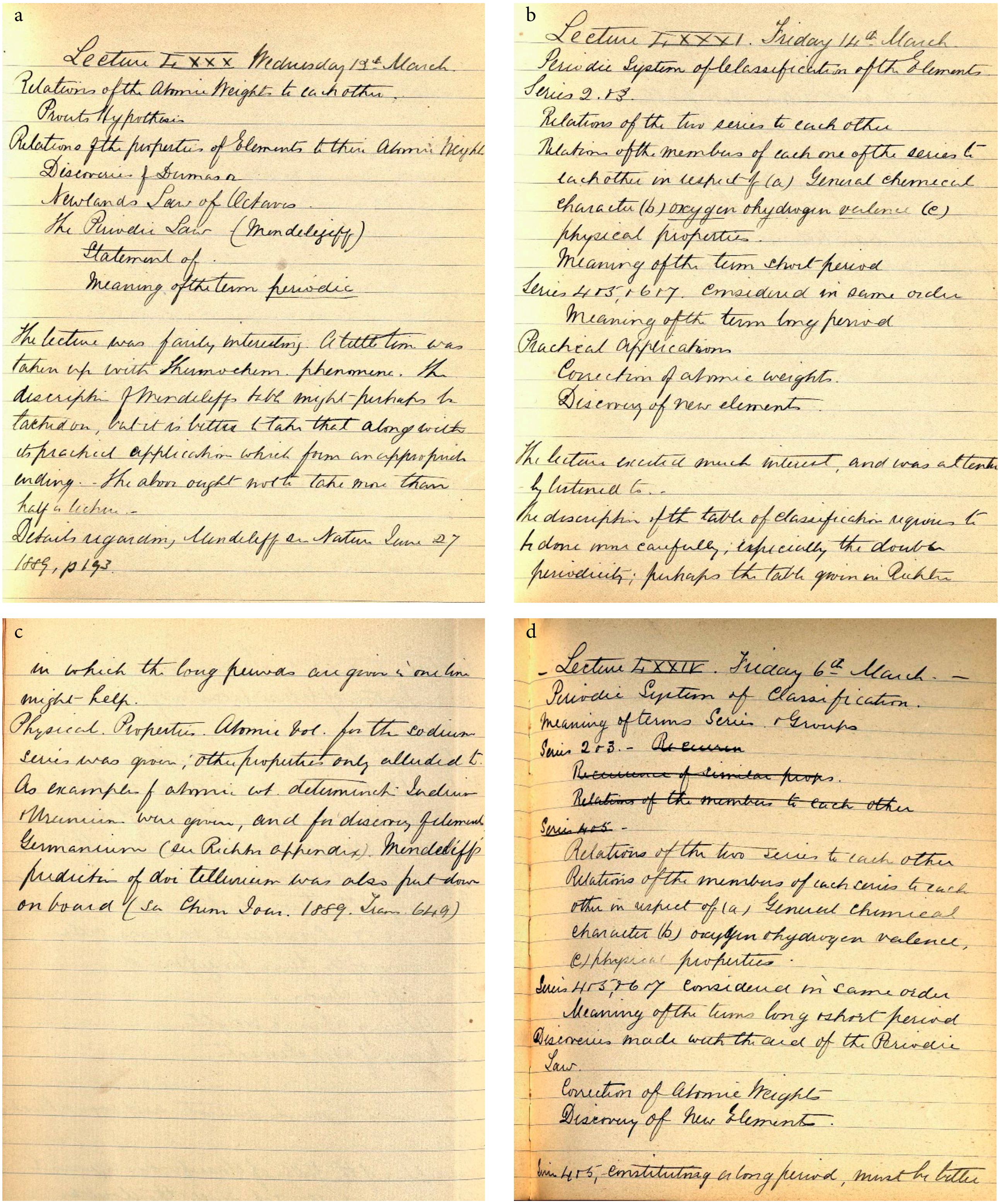

Figure 9. Thomas Purdie Syllabus of Lectures. Courtesy of University of St Andrews Library: ms38620.

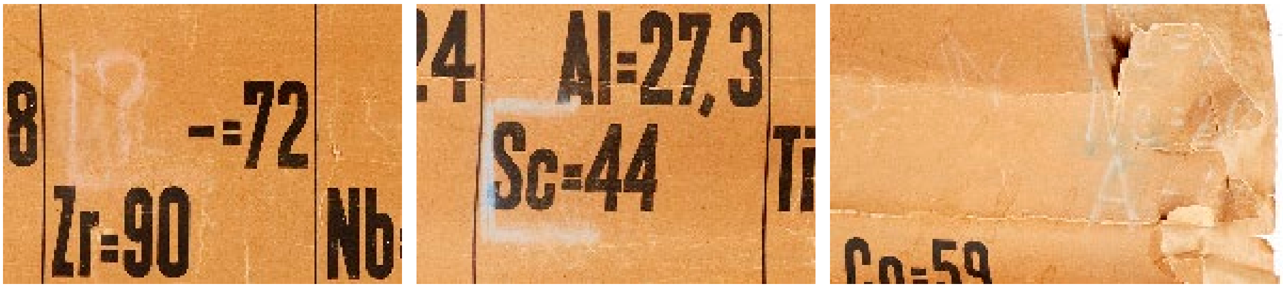

Figure 10. Close-up views of the St Andrews wallchart table showing chalk markings. R. Alan Aitken, 2014.

Some references to the pedagogical use of the periodic table wallchart can be extracted from Purdie's notes for this particular lecture. One of them is the mention of the relations of the members of each of the series to each other in terms of oxygen and hydrogen valence, a characteristic that is depicted in the head of the columns of this wallchart as in Mendeleev's 1871 table, but that was not common for all the tables at the time.

Another example is Purdie's allusion to the practical use of the periodic table for the discovery of new elements, mentioning particularly germanium. Here we must return to the St Andrews table as it was discovered in 2014 and observe the chalk additions to remark new or missing elements. Although it is not possible to ascertain if Purdie drew these marks, they certainly illustrate the interaction with the wallchart and thus the pedagogical use of the table. A close-up view shows the addition of a question mark in the space for germanium and underneath of this chalk addition the symbol Ge can be faintly noticed, suggesting that the marks on this space were erased and filled up according to the message that wanted to be conveyed to the student audience (Figure 10a). Also scandium, the latest element discovered before the printing of the St Andrews periodic table, is singled out in the wallchart with a chalk mark highlighting its symbol (Figure 10b).

Purdie seemed to be very attentive to his students and he often got feedback from them about the lecture and its contents. For instance, in the notes from his lecture on Wednesday 6th of November, 1889 he wrote:

"The interest of lecture pretty well sustained. The facts about the life of Lavoisier seemed to interest."

When trying to explain concepts in the most logical or intuitive way, Purdie mentions textbooks and, if needed, he goes away from the representation of the periodic law in the wallchart that he purchased recommending other periodic tables that might help to understand difficult messages as, for instance, the idea of double periodicity mentioned in Lecture LXXXI. The textbook that he uses, mentioned in 'The table given in Richter" and "Richter appendix" is the fifth German edition of Victor von Richter's *Lehrbuch der anorganischem Chemie*, or the translated edition published in London in 1887.[27] Von Richter (1841–1891), a German chemist, published the first edition of his textbook in 1875, followed afterwards with subsequent editions in German, Russian, English and French. In his book, he used the periodic arrangements of both Lothar Meyer and Mendeleev, thus contributing to their dissemination.

The article cited by Purdie in the last line of his notes for the lecture LXXXI, refers to a lecture on the periodic table given by Mendeleev at the Chemical Society of London (Faraday Lecture, 1889), where he forecasts an element analogous to tellurium, dvi-tellurium, that must be positioned after bismuth and with a predicted atomic weight of 212.[28] The characteristics of this predicted element match what we now call polonium.[29]

The following academic year (1890-91) Purdie dedicated a lecture to the "Classification of Elements in accordance with their atomicity" along with the "meaning of the term valency" and the "Classification of elements in accordance with their valency." (Lecture XXXIII. Tuesday 16th December 1890)

During the same session he dedicated one lecture to the introduction of the periodic law and during the following lecture he developed the notion of the periodic system (Figure 9d (recto)).

- Lecture LXXIV Friday 6th March. –
Periodic System of Classification.
Meaning of terms Series & Groups
Series 2 & 3. – Series 4 & 5 –
Relations of the two series to each other
Relations of the members of each series to each other in respect of (a) General Chemical character (b) oxygen & hydrogen valence, (c) physical properties.
Series 4 & 5, & 6 & 7 considered in same order
Meaning of the terms long & short period
Discoveries made with the aid of the Periodic Law.

Correction of Atomic Weights
Discovery of New Elements.

Series 4 & 5, constituting a long period, must be better

Verso:

described. Their [chemical] relations might be given,
expressly omitting the members of Group VIII, so
as to emphasize the fact that they are a repetition
of series 2 & 3.

Going forward a decade, in the summary of lectures for the session 1902-03, Purdie introduces a new lecture on the very recent discovery of the noble gases -W. Ramsay (1852–1916) and Lord Rayleigh (1842–1919) had announced the discovery of argon only 7 years earlier, followed closely by the discovery of helium, neon, krypton, xenon and radon.[30] Here again the use of the St Andrews periodic table as a teaching tool is apparent observing the chalk additions to fill in the noble gases, possibly when their discovery was explained to the students (Figure 10c).

Lecture LXVI Friday 6th Febry.
– Recently discovered atmospheric gases –
Argon. History of its discovery. Rayleighs' & Ramsays' Methods of isolating the gas. Its properties; probable Atomic Wt.
Helium. Existence in the sun; discovery
of terrestrial Helium by Ramsay. Isolation of the Helium Group of Gases. Helium, Neon, Argon, Krypton, Xenon by fractional distillation.

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Lecture LXVI Continued.
Numerical relations of the Atomic Weights
Prout's Hypothesis. Its significance.
Co-relation of the Atomic Weights & Properties of the Elements
Uniformities in the Atomic Weights of Chemically Similar elements. Newland's "Law of Octaves". Periodic Law. Meaning of the term periodic.
Periodic System of Classification
Series II & III. Illustration of the recurrence of similar properties at definite intervals. Uniform variation of properties in each series in respect of: 1. Electron affinity. 2. Oxygen valence. 3. Hydrogen valence. 4. Physical Properties
Meaning of term Period
Series IV & V Constitute a long period of 17 elements, consisting
of 2 short periods of 7 elements each, + 3 transitional elements
Application of the Classification
Correction of Atomic weights
Prediction of undiscovered elements

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The above is a complete syllabus. In this course the facts were
given very briefly. Lecture LXVI extended the illustration of recurrence of similar properties at definite intervals."

It is important to note that in this lecture Purdie introduces for the first time the concept of electron affinity. It is not just a mention in passing, as Purdie gives to this property of an element a special treatment since he mentions it before the oxygen and hydrogen valence that had been the properties highlighted in his lectures from previous years. This shows the evolving nature of his lectures and how he changes the syllabus and his interaction with the periodic table according to the latest discoveries. The electron affinity of an element can be defined as the amount of energy released when a neutral atom accepts an electron to form an anion. Considering that just 5 years had passed since the discovery of the electron by J. J. Thomson (1856–1940), the inclusion of this property in Purdie's description of the table shows his appreciation of the importance of having for the first time a measurable property on which to base the periodic arrangement of the elements. Across the periodic table, the electron affinity increases from left to right across periods and upward for the groups, i.e. metals generally have a lower electron affinity than nonmetals, with the exception of the noble gases.[31] Explaining this new concept to students in 1902, shows that Purdie was keeping abreast of the latest discoveries and understanding their importance.

These concrete examples extracted from Purdie's notes illustrate how the teaching of the periodic system evolved in the years that followed the publication of the St Andrews periodic table wallchart. Interestingly, this gradual change can also be attested in the chart itself, where the chalk marks, the handwritten elements that filled in empty spaces and the added symbols of the gases unknown at the time of the table's publication, show the didactic use of this periodic table at the University.

CONCLUSION

The delivery of the periodic table and other teaching wallcharts to the Department of Chemistry at the University of St Andrews in the late 1880's coincided with the start of a remarkable period of development in the fortunes of the department which led to its becoming, within 20 years, a world-renowned centre for research in carbohydrate chemistry. The small numbers of students at that time typically went on to successful scientific careers in which detailed awareness of the latest discoveries of new chemical elements and their properties would be important. Use of the latest available visual aids was only to be expected of an excellent teacher like Thomas Purdie. What is remarkable is that the 1885 periodic table wallchart was rolled up and stored away once it was rendered obsolete by the discovery of new elements such as the noble gases in the 1890's and survived undamaged for the next 120 years allowing us to enjoy it today.

Of almost as great significance are the notebooks of Thomas Purdie, which have also survived to the present day. In them he gives a detailed description of what he taught in each lecture and an evaluation of how he thought the various parts of the lecture were received by his students. Some of the lectures he records possibly correspond with the use of the wallchart in teaching. Hand written annotations to the wallchart can be seen as illustrating the discovery of new elements and other changes in the understanding of the periodic system in the decades after Mendeleev published his key hypothesis. The interplay between the wall chart and Purdie's notes gives a deep and unusual insight into the teaching of chemistry in the late 19th century and even sheds some light on the teacher student relationship.

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