The International Year of the Periodic Table: 150 Years of Arranging Elements

by Thomas Ott, ASPE

Those of you who are not chemists may not be aware that the United Nations has declared 2019 to be the "International Year of the Periodic Table." This recognizes 150 years since Dmitri Mendeleev presented his periodic arrangement of the elements to the Russian Chemical Society on March 6, 1869, just a few months before Lothar Meyer of Germany published an equivalent table. In 1882, the Royal Society in England honored both Mendeleev and Meyer with the Davy Medal for their work.[1]

The periodic table allows chemists to predict many chemical and physical properties of elements based upon knowledge of other elements in the table. Mendeleev was the first to arrange the elements known at that time in a way that permitted such predictions, though he was not the first to notice how certain sets of elements resemble each other. Johann Wolfgang Döbereiner, in 1829, noticed that some elements can be arranged in triads, in which the mass of the central atom was approximately the average of the other two (what many references call atomic weights are really atomic masses).[2] For example, the relative masses of the elements lithium and potassium are about 7 and 39, respectively. Both elements react with water to form bases, and most of their compounds are water-soluble. Sodium, which also forms a base in water and has water-soluble compounds, has a mass of 23, the average of 7 and 39. Another triad, chlorine-bromine-iodine, grouped three rather reactive elements that all form acids in water and whose masses are about 35, 80, and 126 respectively, fitting the mathematical pattern. However, not all elements can be put into such a grouping.

On February 7, 1862, John Newlands in England published the first table that included many, but not all, of the elements in order of their atomic masses, arranged in sets of seven to eight elements called octaves.[3] In a way similar to octaves in a musical scale, every eighth element was to have properties similar to the element in the same place on the scale in a previous or subsequent octave. While many elements which are currently grouped together were similarly grouped in Newlands' table (e.g., fluorine, chlorine, bromine, and iodine are in one group; lithium, sodium, and the other alkali metals are in another), other elements were out of place. For instance, cobalt and nickel occupied one space (and there were other such two-element spaces) on the same step as fluorine and chlorine; and oxygen, gold, and iron appeared to be similar. Also, the correct masses of some elements were not known, causing them to be misplaced. Newlands' table was not accepted for publication by the Society of Chemists, but eventually the Royal Society honored him with a Davy Medal as they had honored Mendeleev and Meyer.

Of note, the American Chemical Society (ACS) produced a calendar for 2019 showing February 7th, not March 6th, as Periodic Table Day. The ACS apparently based Periodic Table Day on the date that John Newlands published the first version of the periodic table in 1862. However, with 2019 marking the 150th year since Dmitri Mendeleev presented his period table arrangement on March 6, 1869, it's interesting that the ACS chose February 7th as Periodic Table Day rather than March 6th.

In 1864, French geologist Alexandre Emile Béguyer de Chancourtois created a three-dimensional periodic chart in which elements with similar properties were aligned under each other.[4] Its geology focus did not help it gain acceptance with chemists. Also in 1864, Englishman William Odling prepared a table similar to Newlands', including 57 of the 60 known elements (more elements than Newlands' used) and was based on proportional numbers of the atomic masses (see Figure 1).[5] Odling's table resembled Mendeleev's, but the periods were of uneven length, and some elements were misplaced.

			Ro 104	Pt 197
			Ru 104	Ir 197
			Pd 106·5	Os 199
H 1	"	"	Ag 108	Au 196·5
"	"	Zn 65	Cd 112	Hg 200
L 7	"	"	"	Tl 203
G 9	"	"	"	Pb 207
B 11	Al 27·5	"	U 120	"
C 12	Si 28	"	Sn 118	"
N 14	P 31	As 75	Sb 122	Bi 210
O 16	S 32	Se 79·5	Te 129	"
F 19	Cl 35·5	Br 80	I 127	"
Na 23	K 39	Rb 85	Cs 133	"
Mg 24	Ca 40	Sr 87·5	Ba 137	"
	Ti 50	Zr 89·5	Ta 138	Th 231·5
	"	Ce 92	"	
	Cr 52·5	Mo 96	V 137	
	Mn 55		W 184	
	Fe 56			
	Co 59			
	Ni 59			
	Cu 63·5			

FIGURE 1: William Odling's Periodic Table, 1864.[a]

Gustavus Hinrichs published a periodic spiral chart in 1867 (see Figure 2) in which it was easier to see the groupings of elements than with other tables, but not all the groups were correct.[6]

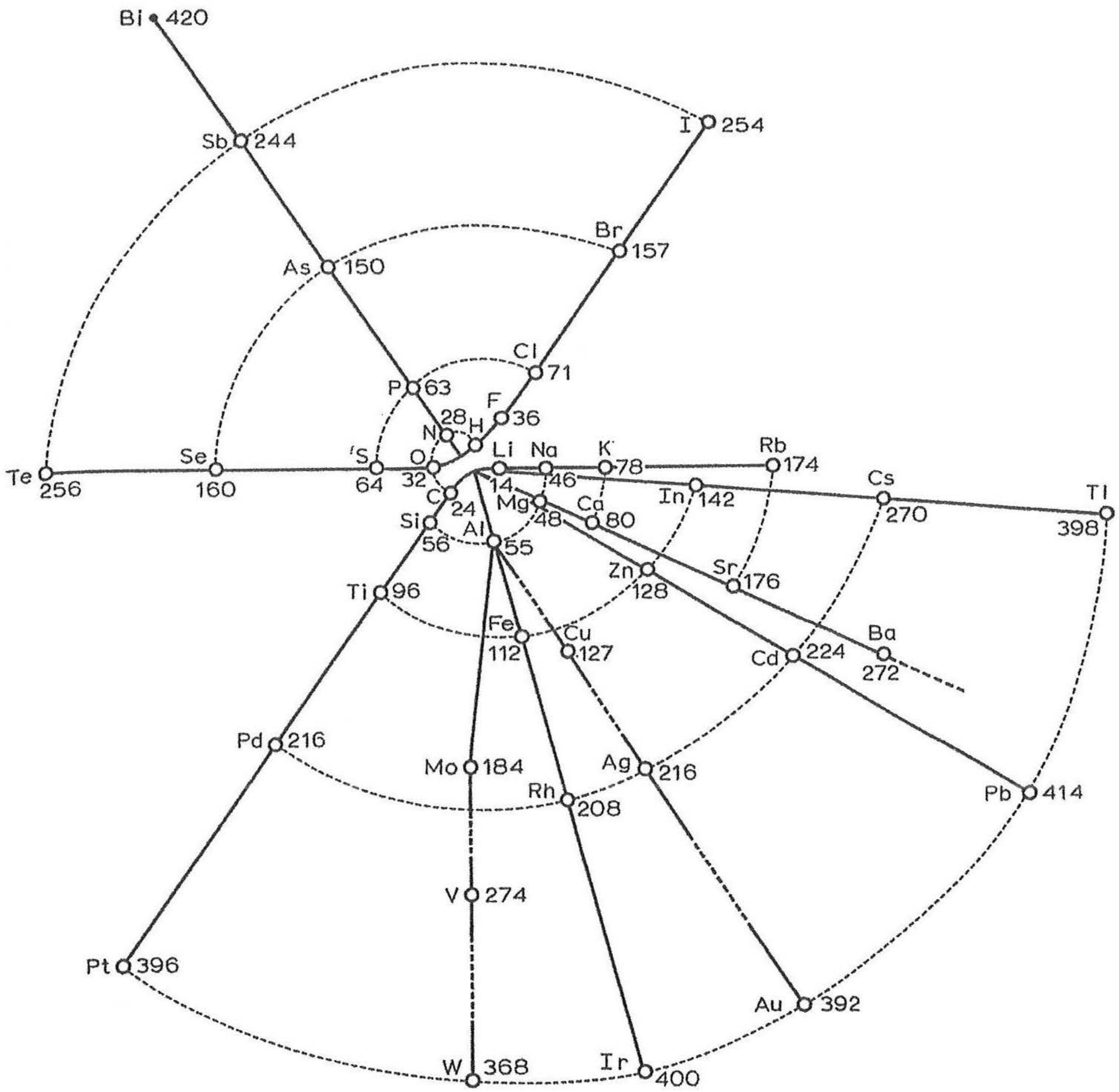


FIGURE 2: Gustavus Hinrichs' Periodic Table, 1867.[b]

Mendeleev’s table in 1869 (see Figure 3) used some of the same organizational techniques of Newlands and Chancourtois, such as arranging the elements in order of their atomic masses.[7] Mendeleev put elements in groups based upon their chemical properties, in particular, the formula of the compound that each element forms with oxygen. In his periodic table, certain properties of the elements recurred in each row (period) so that elements in a column formed a group. A particular insight that made Mendeleev’s table most useful is that he recognized that some elements were yet to be discovered. For instance, in order to preserve the periodic repetition of properties, he left two spaces between zinc and arsenic because arsenic most resembled phosphorus, not aluminum or silicon. He even predicted many of the properties of the missing elements (gallium and germanium, as well as scandium elsewhere) and their compounds; and when those elements were later discovered, Mendeleev’s predictions were fairly close to the actual values. He also suggested that tellurium should be ahead of iodine, despite tellurium having a higher atomic mass, and he presumed incorrectly that the mass of tellurium was wrong.

Mendeleev’s table did not look like today’s table. There were no boxes. The right side did not contain the noble gases because none were known at the time, but it did contain sets of four elements each so that periodicity was preserved elsewhere. In the modern form, rows 4 and 5 are combined, as are rows 8 through 11. In 1879, Mendeleev prepared a table in which the transition metals (e.g., iron, gold, and other elements that were in the split groups on the original table) were in separate columns similar to the common arrangement today (see Figure 4). However, this format did not catch on at the time, and the transition elements were not matched with the main groups as is now considered to be correct. For instance, magnesium was above zinc

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 3: Dmitri Mendeleev’s original periodic table, 1869.[c]

										even elements						
										I	II	III	IV	V	VI	VII
										H						
										LI	Be	B	C	N	O	F
										Na						
even elements										odd elements						
I	II	III	IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII
										—	—	—	—	—	—	—
—	—	—	—	—	—	—				—	Mg	Al	Si	P	S	Cl
K	Ca	—	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	—	—	—	—
Rb	Sr	Yt	Zr	Nb	Mo	—	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	J
Cs	Ba	La	Ce	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	Er	Di?	Ta	W	—	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	—	—
—	—	—	Th	—	U	—	—	—	—	—	—	—	—	—	—	—

FIGURE 4: Dmitri Mendeleev's 1875 periodic table.[d]

rather than calcium. However, when the noble gases were discovered between 1894 and 1897, they could be accommodated by adding an eighth column at the end. Mendeleev accepted the column of the noble gases in 1900.[8]

In the 1800s, nobody had any explanation as to why elements should show periodic properties. The structure of the atom was unknown. However, the negatively charged electron was discovered in 1897, and the positively charged proton in 1917.[9] In 1914, Henry Moseley of England determined that the positive charge in the nucleus of an atom—the atomic number which is equal to the number of protons—determines the identity of the element. He was able to order the elements by atomic number and determine the correct order of elements with similar masses, such as cobalt and nickel, as well as indicate atomic numbers for which no element had been found. Later, all those elements were either found in nature (e.g., hafnium and rhenium) or created artificially (e.g., technetium and promethium).[10]

In the 1920s and 1930s, the electronic structures of the atoms were worked out. It was found that the structure of the periodic table could be explained largely by the arrangement of the electrons in shells and subshells.[11] Each shell has subshells, and there are orbitals within the subshells. The lowest energy subshell (the s sublevel) can hold 2 electrons. The next lowest (the p sublevel) holds up to 6. The third (the d sublevel) holds up to 10, and the fourth (the f sublevel) up to 14 electrons. The first shell contains only the lowest energy sublevel, the s sublevel, and one new sublevel is added with each shell. Electrons enter the orbitals in order of lowest energy first (the "aufbau principle" from German for "building up"). A new period begins each time a new shell is opened up. The shells increase in energy as they get farther out from the central nucleus, which contains the protons and neutral neutrons.

This is straightforward for the first two shells, with sublevels designated 1s, 2s, and then 2p. In the third shell, however, the increase in energy

IA																	8A
1	2A											3A	4A	5A	6A	7A	18
H	2											13	14	15	16	17	He
Li	Be	3B	4B	5B	6B	7B		8B		1B	2B	B	C	N	O	F	Ne
Na	Mg	3	4	5	6	7	8	9	10	11	12	Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Ac**	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn	Nh	Fl	Mc	Lv	Ts	Og

*	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
**	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

FIGURE 5: The most common current form of the periodic table (by the author).

going from the 3s to the 3p and then to the 3d subshells puts the 3d subshell at a higher energy value than the 4s. Thus, the 4s starts a new shell before the third shell is complete. The same situation occurs for all the other levels as well. The f orbitals start with the fourth shell, but they are higher in energy than the 6s sublevel and appear at a similar energy value as the 5d sublevel.

The electron configurations explain the arrangements of elements into the groups and spaces on the table that we are most familiar with. The first two columns are where the s electrons are outermost, and the last six columns are where the p electrons are outermost. In the fourth row, where the 4s electrons have already started a new shell, there is an insertion of the 10 transition-metal elements. The 14 elements at the bottom are elements in which the f orbitals are filling up. The outermost electrons, called valence electrons, are always in the s or p orbitals, and chemistry is most likely to involve taking electrons away or adding electrons to those outer orbitals. Each column of elements on the left and right sides has the same number of valence electrons and, consequently, similar chemical and physical properties to the other elements in the same group.

For the transition elements, the electrons are being added to an inner shell, and the inner transition metals at the bottom are having electrons added two shells in. The inner transition elements are very similar in their chemistry and are thus hard to separate. The d and f electrons are not added in the same orderly, predictable manner as the s and p electrons, however. For instance, the 6s, 5d, and 4f orbitals have similar energy values; and the placement of the next electron for each new element is not necessarily what one would expect. Nevertheless, an approximate arrangement (called a configuration) of electrons can be predicted for each element simply by looking at its position in the periodic table.

The common form of the periodic table used today (see Figure 5) clearly shows the blocks where particular subshells are being filled and also makes it easy to see the groups of related elements. For instance, in the first column, lithium (Li), sodium (Na), potassium (K), rubidium (Rb), cesium (Cs), and francium (Fr) are all alkali metals; the second column of beryllium (Be) to radium (Ra) is where the alkali earth metals are found; and so forth. When the transition metals are not separated into 10 intervening columns, copper (Cu), silver (Ag), and gold (Au) appear more closely related to the alkali metals than is the case. In 1905, Alfred Werner published one of the first "long form" periodic tables in which there was a block for the transition metals, as there is in the common form today; however, he put beryllium (Be) and magnesium (Mg) above zinc (Zn), not calcium (Na).[12] Niels Bohr and his colleagues also proposed a long form of the periodic table in 1920 with a more accepted arrangement of elements;[13] and Charles Janet came up with a 32-column table in 1928, in which the 14 transition elements were left in the same row as the transition and other elements (Figure 6 shows a modern adaptation).[14]

The treatment of several elements often differed from how they are accepted today. Hydrogen and helium, by their configurations of electrons, appeared above lithium and beryllium; but hydrogen does not show the chemical or physical properties of the alkali metals, and helium is definitely a noble gas. Hydrogen was sometimes placed above fluorine, and helium could appear above beryllium. Some tables put the noble gases at the left, in front of the alkali metals, and ended the period with the halogens (fluorine, etc.). Thorium, protactinium, and uranium were originally placed below hafnium, tantalum, and tungsten.

The Mendeleevian format with interspersed transition elements remained common until after World War II.[15] However, a chemistry textbook published by H. G. Deming in 1923 used a condensed version of the long form in which the inner transition elements, the f groups, were placed as a footnote to enable the table to fit conveniently on the page.[16] This style of table was also distributed by chemical companies. Deming introduced the convention of labeling the columns with Roman numerals, with A for the representative groups (where s and p electrons are added) and B for the transition elements. Deming put the noble gases at the left and put boron and aluminum above scandium. A number of periodic tables from the 1920-1945 period can be found online.[17]

The condensed 18-column periodic table became popular after World War II. The major changes have been the creation of new elements and the discovery of missing elements francium and astatine. In 1945, Glenn Seaborg proposed placing thorium, protactinium, and uranium in a separate bottom row underneath cerium and the other lanthanide (4f) elements, a change that was eventually accepted.[18] Since that time, new elements have been created which correctly take the place of where thorium and the rest were originally placed. Also, the columns were designated IA, IIA, IIIB, etc., IB, IIB, IIIA, etc., in the US and Britain, where the d block had a B and the s and p were A, as Deming said. However, in Germany, the designations went from IA to VIIIA and then started IB to VIIB and 0. What comprised group IVB in Germany was

																													H	He	1
																													Li	Be	2
																							B	C	N	O	F	Ne	Na	Mg	3
																							Al	Si	P	S	Cl	Ar	K	Ca	4
													Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr	5
													Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	Cs	Ba	6
La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	Fr	Ra	7
Ac	Th	Pa	U	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg										8

FIGURE 6: A fairly recent periodic table based on Charles Janet's 1928 table.[e]

IVA in the US, and vice versa. A compromise was reached by labeling the groups 1 through 18 without any Roman numerals or letters.[19] The main controversy now is where to start and end the lanthanide and actinide series (the f block) which is placed at the bottom for space reasons. For instance, both lanthanum and lutetium have a single 5d electron, though lanthanum has no 4f electrons, and lutetium has 14. Some tables put lanthanum after barium and end the bottom row with lutetium, while others put lanthanum with the other transition elements at the bottom and have lutetium follow barium. Some put lanthanum through lutetium at the bottom and just have a note in the box after barium. (The treatment of actinium through lawrencium after radium matches that of lanthanum through lutetium.) A committee called the International Union of Pure and Applied Chemistry (IUPAC) is working on a solution.[20]

While the 18-column table with the inner transition elements at the bottom seems established as the form in which the periodic table is most likely to be presented, various other arrangements have been proposed.[21] Some of these have the elements arranged in a spiral pattern, such as the one by Theodore Benfey in 1964 (see Figure 7).

Spiral tables avoid the large gaps where the d and f subshells are being filled, but many of the boxes do not leave space for much information. Also, some properties, such as the number of valence electrons (the number of outermost s and p electrons), are not as obvious. The spiral table in

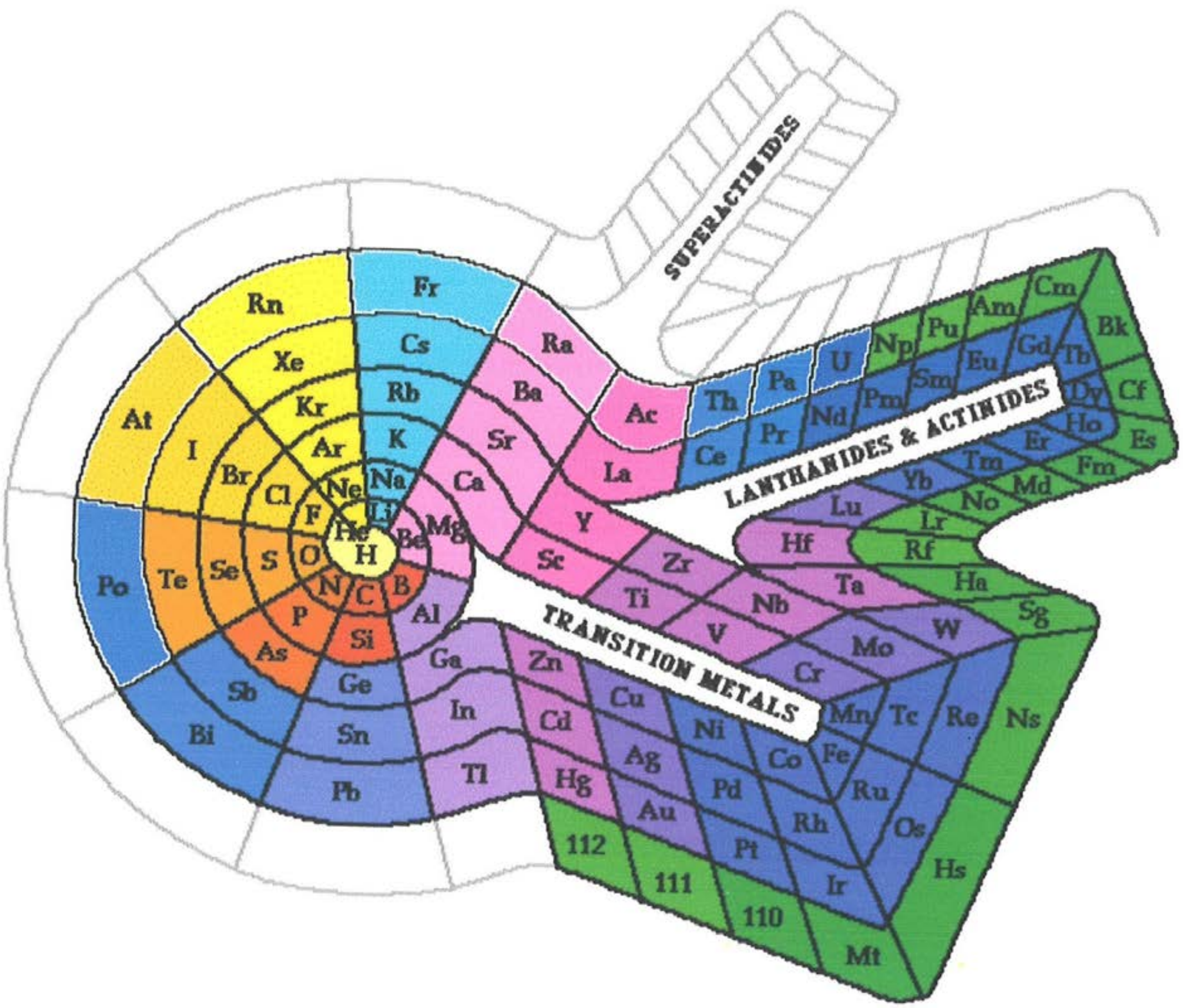


FIGURE 7: Theodore Benfey's periodic table.[f]

Figure 7 does leave space for "superactinide" elements where the g subshell of the 5th shell will finally start to fill up. Some more traditional periodic tables also have figured out how to accommodate these new elements, generally by new rows at the bottom. It is speculated, however, that if elements with such high atomic numbers were to be created (which is harder to do as the number of protons and neutrons increases), at some point, relativity effects may cause the ordering of elements by atomic number to no longer work.[22]

Triangular periodic tables, such as that of Emil Zmacynski (see Figure 8), show relationships between elements in the correct groups but take up a lot of space.

Some periodic tables are meant to work in three dimensions, such as that of Timothy Stowe, who based his table on quantum numbers (see Figure 9). Such a table is impractical for a two-dimensional depiction in a textbook. When I showed my introductory chemistry classes a picture of Stowe's table, they were universally glad that it didn't catch on. (Apparently, Stowe never published anything after that table, and nobody has been able to find out what happened to him.[23]) For ease of use, the current form is probably here to stay.

The periodic table is also used for decorative purposes. Many of these examples can be seen at the Chemical & Engineering News webpage, which shows all the entries in a contest held by the American Chemical Society earlier this year to find occurrences of the periodic table in art, housewares, clothing, and other contexts.[24] For example, one person (that person being me) made a three-dimensional periodic table on an egg using the Ukrainian pysanki decorating technique (see Figure 10).

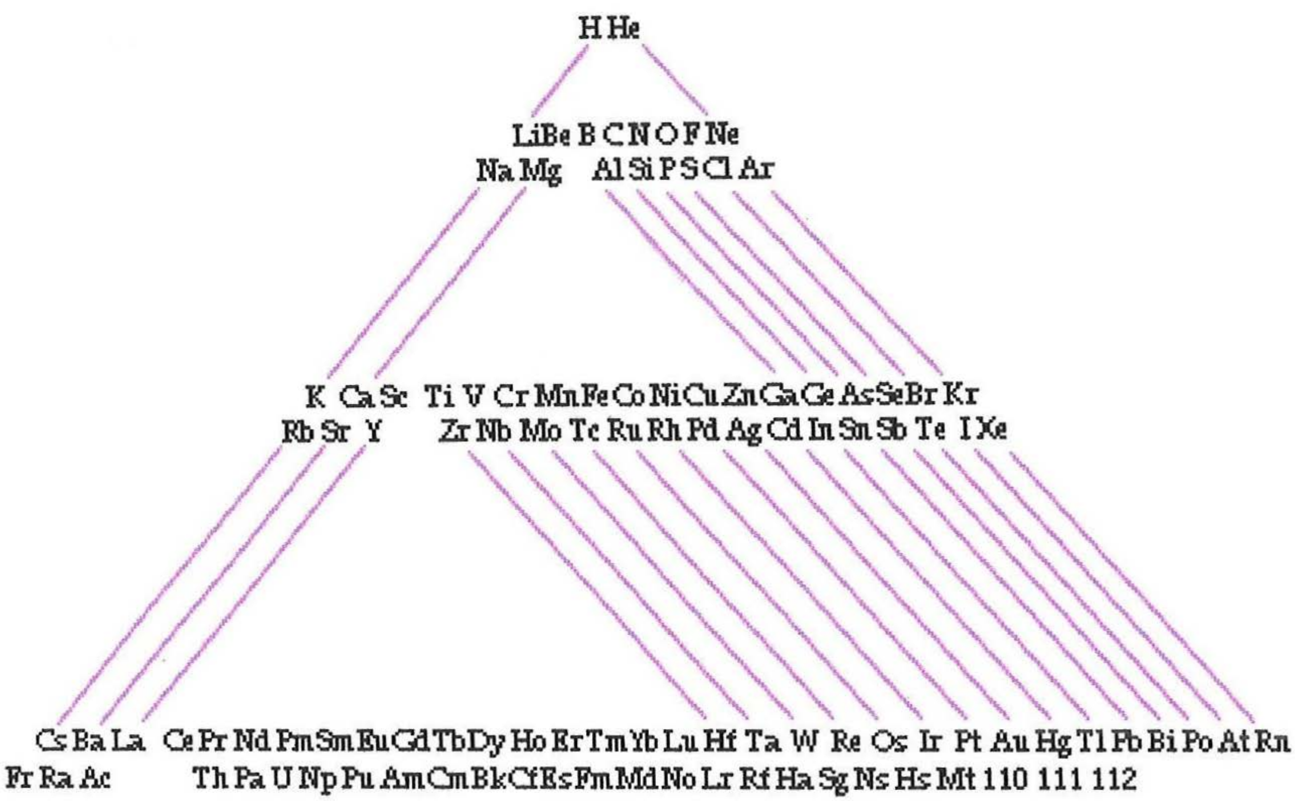


FIGURE 8: Emil Zmaczynski's periodic table.[g]

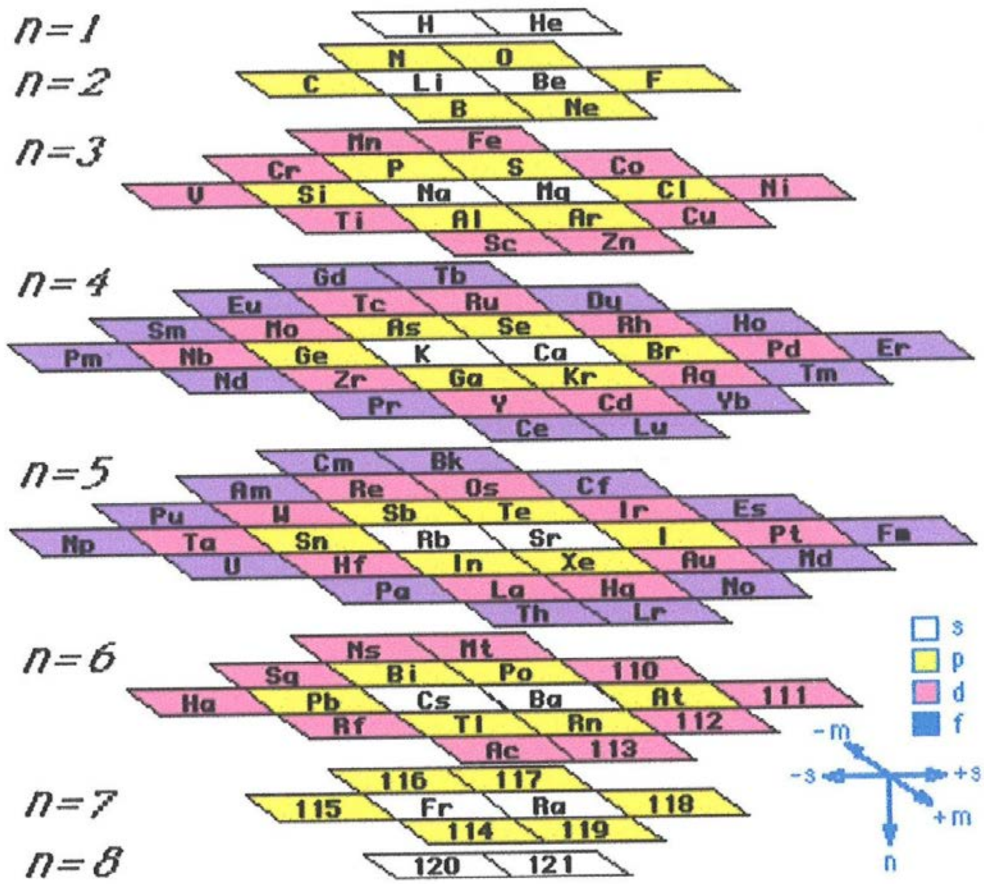


FIGURE 9: Timothy Stowe's periodic table.[h]

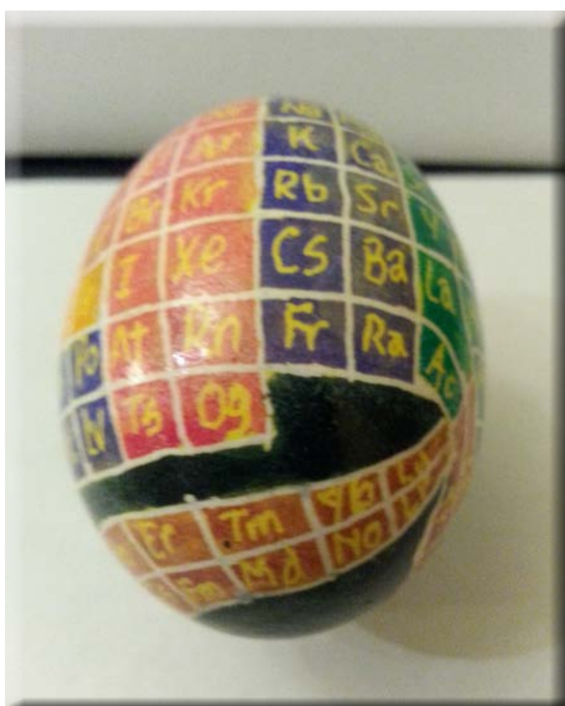


FIGURE 10: *The Periodic Table on an Egg* (by the author).

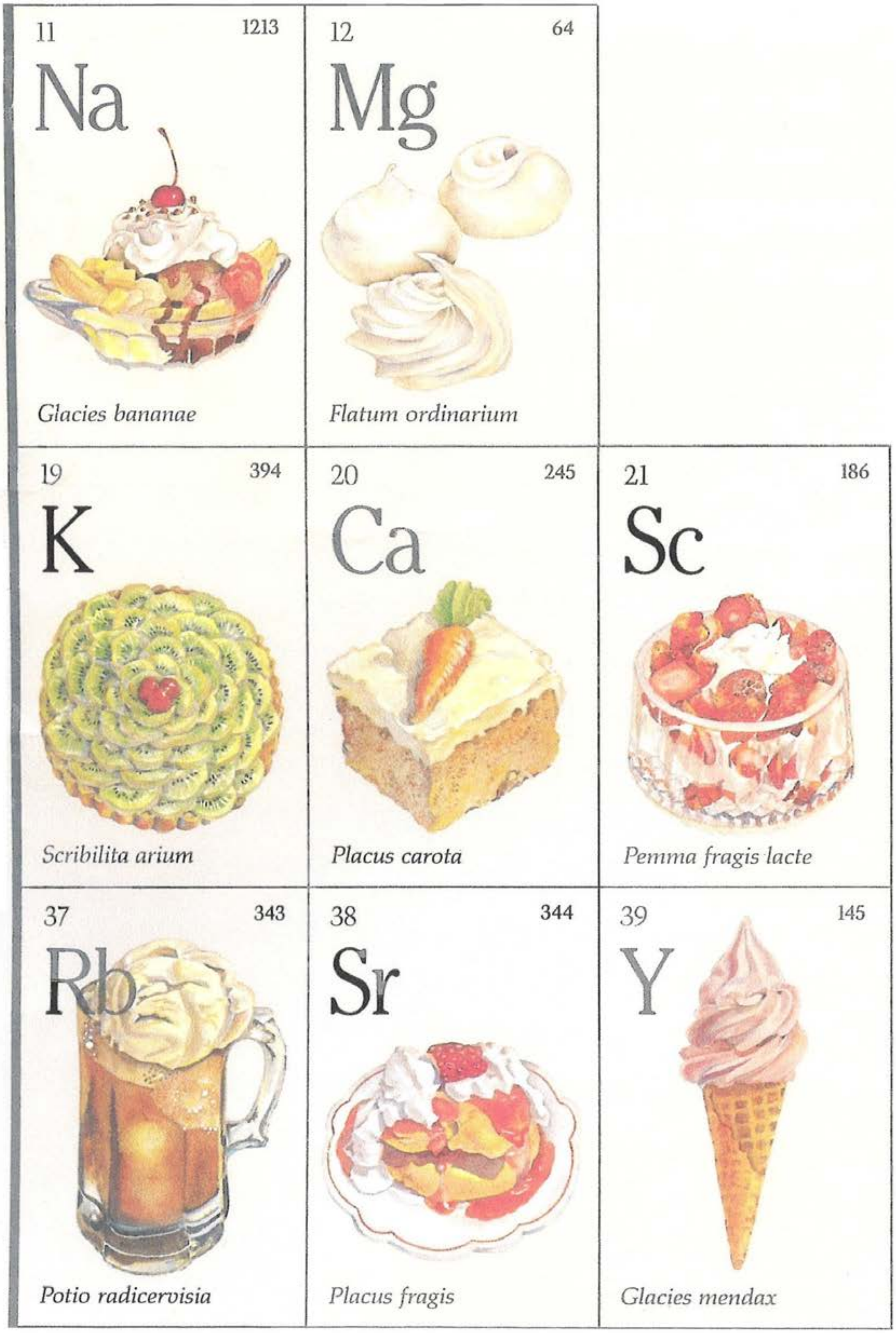


FIGURE 11: A portion of *The Periodic Table of the Desserts*.[i]

Since the egg was in three dimensions, I was able to create the table as a continuous line, where the line is diverted to the bottom to accommodate the inner transition elements and comes back up to align with the transition metals. However, I still had to leave gaps between hydrogen and helium, beryllium and boron, and magnesium and aluminum. Other entries show periodic tables made from building blocks, bathroom tiles, cups, cupcakes, Jell-O molds, and socks. Many of you have probably seen the periodic-table shower curtain on the TV show, *The Big Bang Theory*.

The periodic table has also been used to depict topics other than elements. In the late 1980s in a museum gift shop, I first noticed the "Periodic Table of Fruits and Nuts." The symbols of the elements were repurposed to stand for the names of fruits and nuts, e.g., Zn stood for zinfandel grapes, not zinc. Several other such versions are commercially available. I own the periodic table of desserts (see Figure 11), where the caloric count is used instead of the atomic mass, and a fake scientific name was made up for each dessert, similar to species names in biology.[25]

These tables do "cheat" by stopping at element 89 and completely omitting the inner transition elements. Some other commercially created tables that I have seen are based on birds, endangered species, and fish. The American Chemical Society produced a periodic table of elephants (see Figure 12).[26] A picture depicts an elephant for each element in a way that either represents its use (e.g., an elephant balloon for helium) or is a pun from the name (e.g., an elephant dressed like Dorothy with ruby slippers for rubidium).

Then there are tables which use the format but make up symbols to match the terms they want to use. An example is a "Periodic Table of Pirates" t-shirt, which includes "elements" with symbols Dv, Gg, and Ep, among others.[27] In my opinion, the creators of such tables took very little effort to match their creation to the real table, and I do not care for them. However, those are slightly better than tables which not only make up the elements, but also do not use the correct framework, figuring that anything with some boxes lined up with a few gaps looks like a periodic table.

It is possible to make tables where all the words contain letters that match the correct symbols. I have made a number of such tables over the past more than 25 years, combining chemistry and calligraphy. For example, my Periodic Table of Superheroes is illustrated (see Figure 13). I made a previous copy for someone from my church, who chose the topic after winning a customized table in a fund-raising auction.

Some of the other tables I have made are about games, neurology, golf, Oscar-winning films, Harry Potter, gardening, authors, Scotland, and noteworthy women. The assignments of women to element symbols is shown in Figure 14. The two elements that were actually named after women are underlined.

The periodic table can be fun as well as useful!

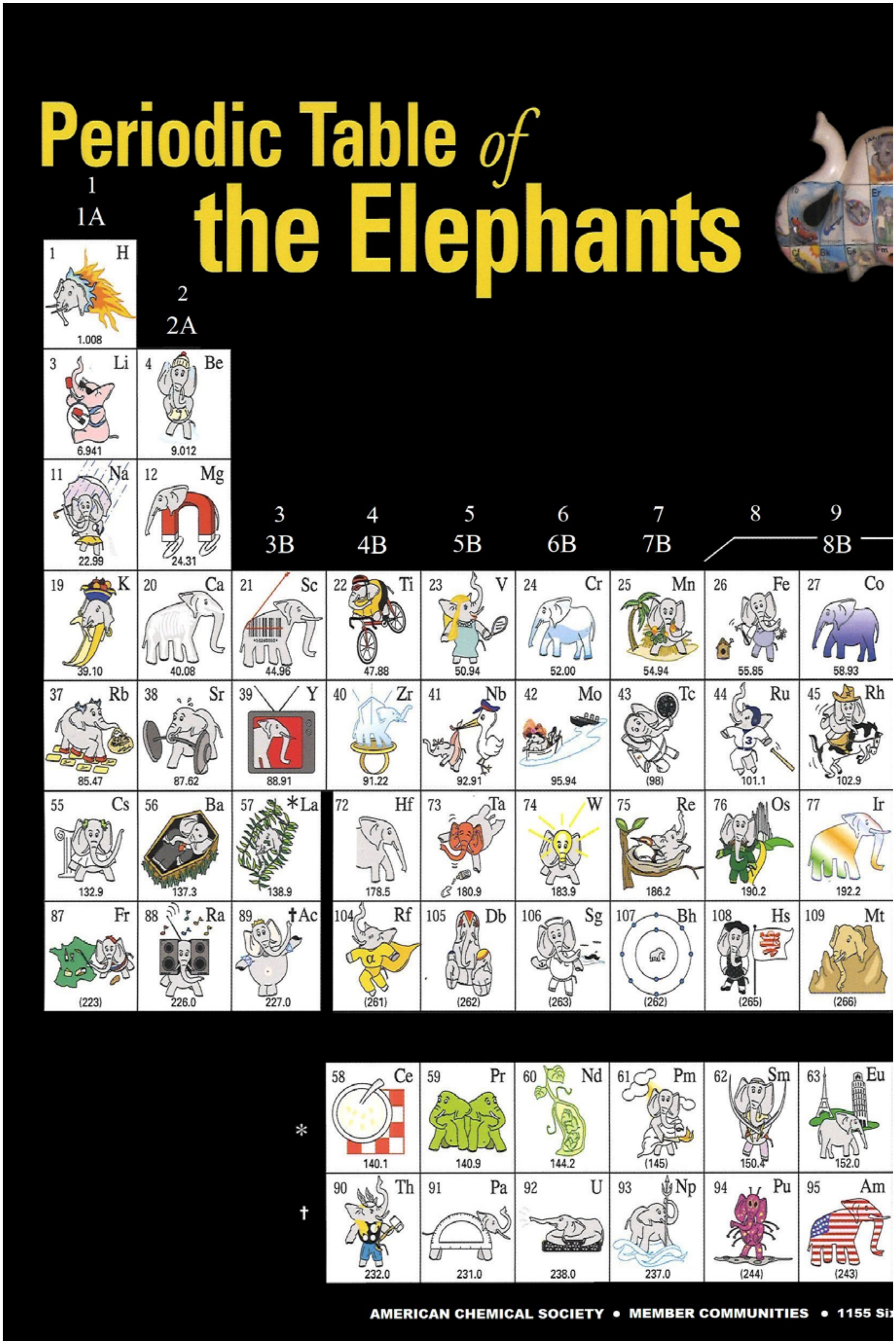
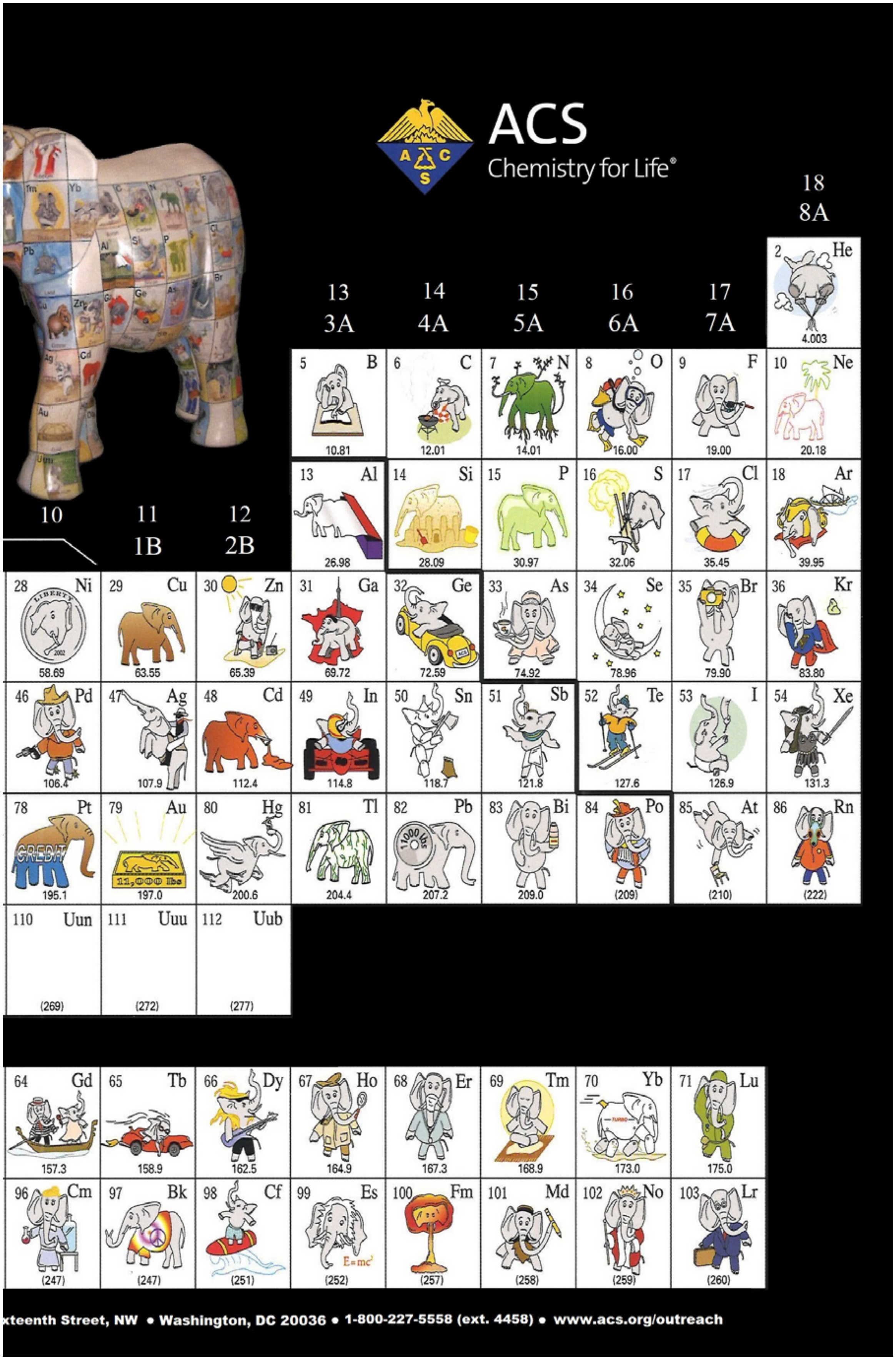


FIGURE 12: *The Periodic Table of the Elephants*[j] (continued on next page).



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7 N 14.01
8 O 16.00
9 F 19.00
10 Ne 20.18
13 Al 26.98
14 Si 28.09
15 P 30.97
16 S 32.06
17 Cl 35.45
18 Ar 39.95
10
11
1B
12
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28 Ni 58.69
29 Cu 63.55
30 Zn 65.39
31 Ga 69.72
32 Ge 72.59
33 As 74.92
34 Se 78.96
35 Br 79.90
36 Kr 83.80
46 Pd 106.4
47 Ag 107.9
48 Cd 112.4
49 In 114.8
50 Sn 118.7
51 Sb 121.8
52 Te 127.6
53 I 126.9
54 Xe 131.3
78 Pt 195.1
79 Au 197.0
80 Hg 200.6
81 Tl 204.4
82 Pb 207.2
83 Bi 209.0
84 Po (209)
85 At (210)
86 Rn (222)
110 Uun (269)
111 Uuu (272)
112 Uub (277)
64 Gd 157.3
65 Tb 158.9
66 Dy 162.5
67 Ho 164.9
68 Er 167.3
69 Tm 168.9
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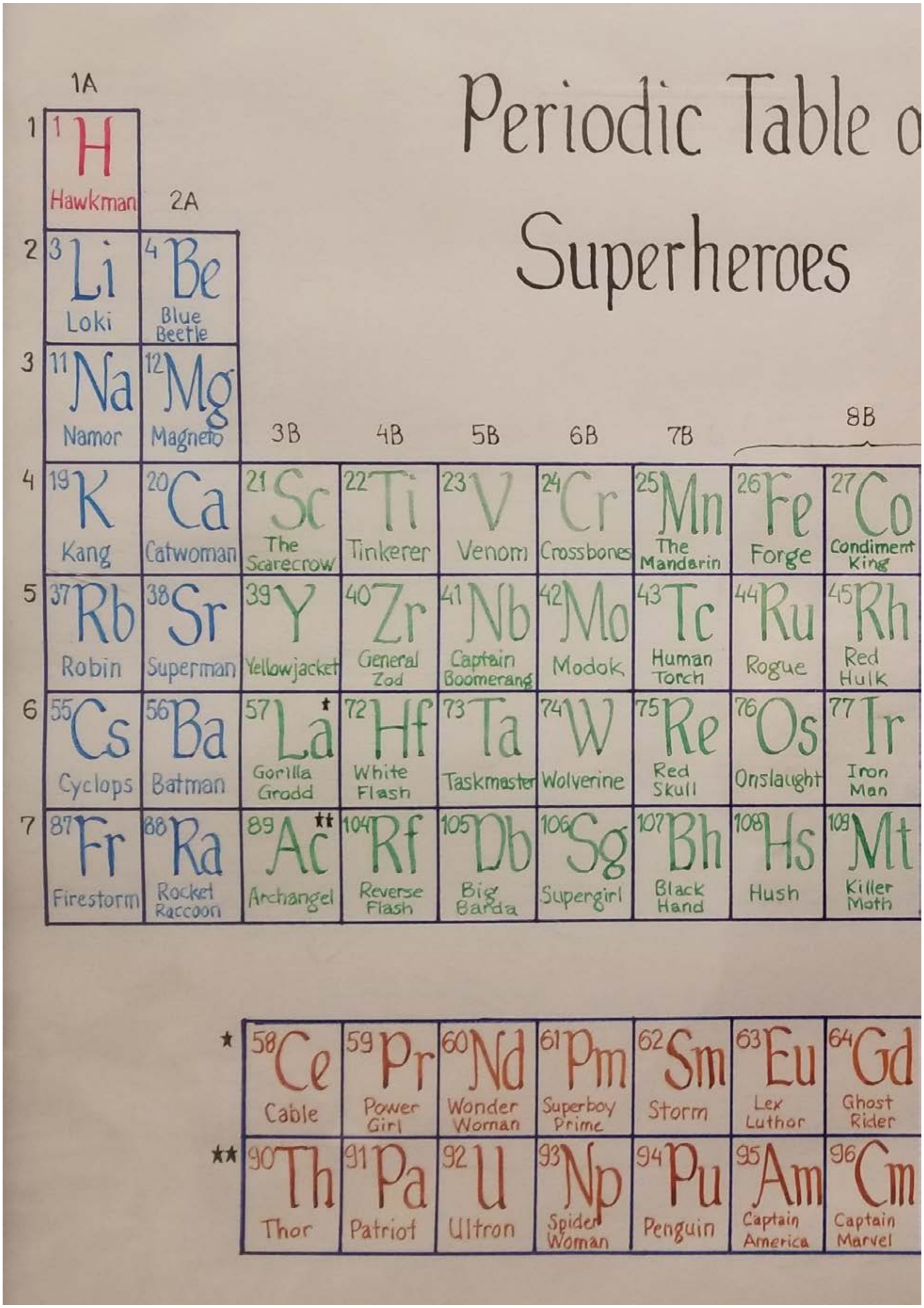
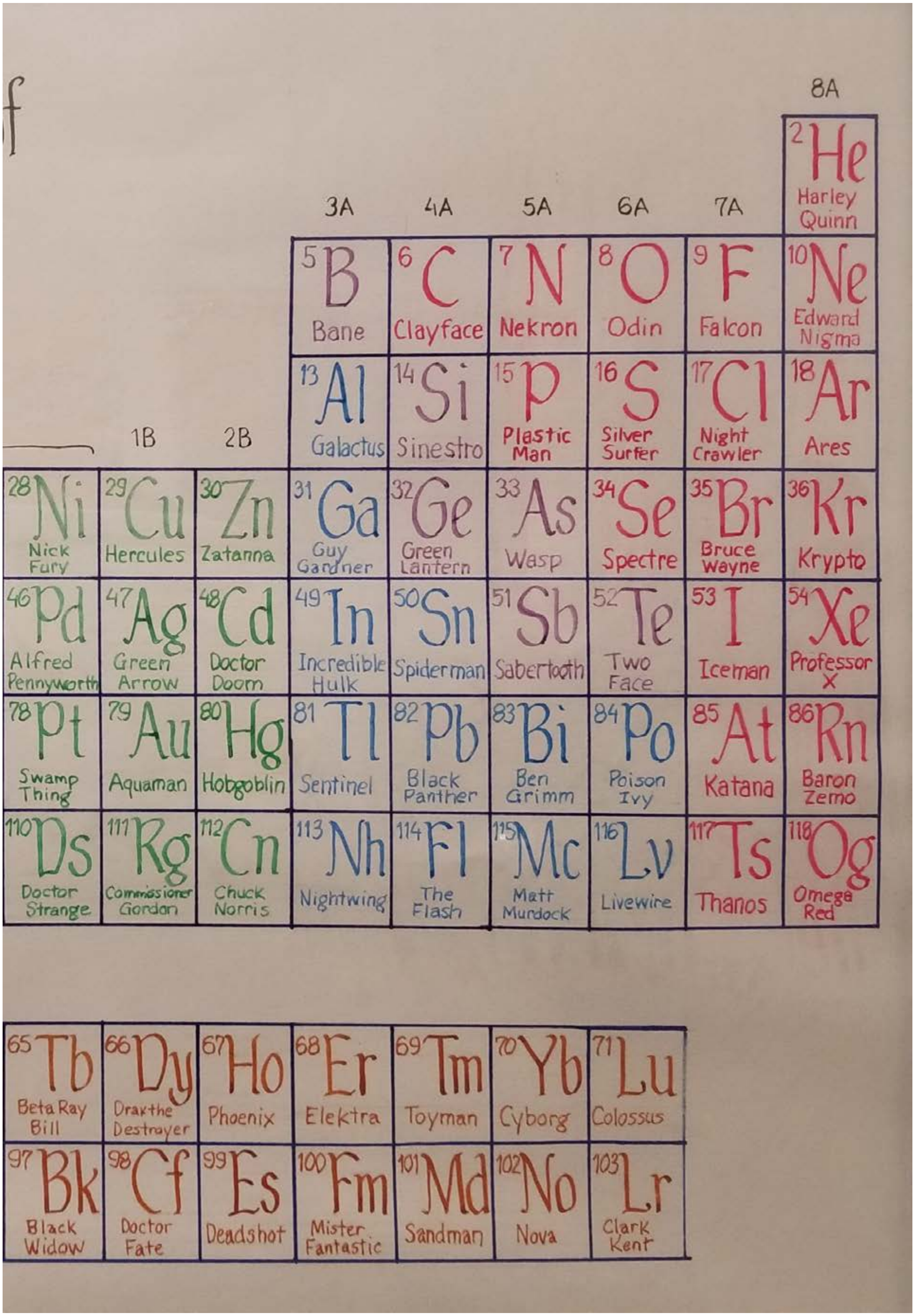


FIGURE 13: *The Periodic Table of Superheroes* (created by the author; continued on next page).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8A
2 He Harley Quinn
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4A
5A
6A
7A
5 B Bane
6 C Clayface
7 N Nekron
8 O Odin
9 F Falcon
10 Ne Edward Nigma
13 Al Galactus
14 Si Sinestro
15 P Plastic Man
16 S Silver Surfer
17 Cl Night Crawler
18 Ar Ares
1B
2B
28 Ni Nick Fury
29 Cu Hercules
30 Zn Zatanna
31 Ga Guy Gardner
32 Ge Green Lantern
33 As Wasp
34 Se Spectre
35 Br Bruce Wayne
36 Kr Krypto
46 Pd Alfred Pennyworth
47 Ag Green Arrow
48 Cd Doctor Doom
49 In Incredible Hulk
50 Sn Spiderman
51 Sb Sabertooth
52 Te Two Face
53 I Iceman
54 Xe Professor X
78 Pt Swamp Thing
79 Au Aquaman
80 Hg Hobgoblin
81 Tl Sentinel
82 Pb Black Panther
83 Bi Ben Grimm
84 Po Poison Ivy
85 At Katana
86 Rn Baron Zemo
110 Ds Doctor Strange
111 Rg Commissioner Gordon
112 Cn Chuck Norris
113 Nh Nightwing
114 Fl The Flash
115 Mc Matt Murdock
116 Lv Livewire
117 Ts Thanos
118 Og Omega Red
65 Tb Beta Ray Bill
66 Dy Drax the Destroyer
67 Ho Phoenix
68 Er Elektra
69 Tm Toyman
70 Yb Cyborg
71 Lu Colossus
97 Bk Black Widow
98 Cf Doctor Fate
99 Es Deadshot
100 Fm Mister Fantastic
101 Md Sandman
102 No Nova
103 Lr Clark Kent

1	H	Hypatia	370-415 ran Library of Alexandria
2	He	Helen Hayes	American actress
3	Li	Lilavati	ancient Indian philosopher
4	Be	Sarah Bernhardt	French actress
5	B	Olympia Brown	clergywoman and social reformer
6	C	Maria Callas	Greek opera singer
7	N	Patricia Neal	actress
8	O	Sadako Ogata	UN high commissioner for refugees
9	F	Dianne Feinstein	US senator from California
10	Ne	Nellie Bly	pioneer journalist
11	Na	Martina Navratilova	tennis star
12	Mg	Martha Graham	choreographer
13	Al	Abigail Adams	feminist wife of President John Adams
14	Si	Beverly Sills	opera singer
15	P	Rosa Parks	civil rights worker
16	S	Sojourner Truth	women's rights worker and former slave
17	Cl	Cleopatra	queen of ancient Asia
18	Ar	Joan of Arc	fought for France in middle ages
19	K	Helen Keller	heroine of deaf and blind people
20	Ca	Catherine the Great	empress of Russia
21	Sc	Sacagawea	Native American guide for Lewis and Clark
22	Ti	Alexandrine Tinne	Dutch explorer of Africa in the 1860's
23	V	Queen Victoria	queen of England
24	Cr	Helen Creighton	Canadian folklorist
25	Mn	Maya Angelou	poet
26	Fe	Geraldine Ferraro	vice presidential candidate

FIGURE 14: The Periodic Table of Noteworthy Women
(created by the author; continued on next four pages).

27	Co	Corazon Aquino	president of the Philippines
28	Ni	Nina Simone	African-American singer, pianist, activist
29	Cu	Imogen Cunningham	photographer
30	Zn	Wu Zetian	625-705 Chinese empress
31	Ga	Gargi	ancient Indian philosopher
32	Ge	Georgia O’Keeffe	American painter
33	As	Aung San Suu Kyi	Burmese Nobel Prize winner
34	Se	Mary Jane Seacole	Jamaican nurse and Crimean war hero
35	Br	Betsy Ross	sewed American flag
36	Kr	Nancy Kerrigan	championship figure skater
37	Rb	Cathy Rigby	gymnast
38	Sr	Sally Ride	astronaut
39	Y	Malala Yousafzai	Pakistani advocate for women’s rights
40	Zr	Mildred Zaharias	athlete
41	Nb	Noel Phyllis Birkby	architect, historian, educator
42	Mo	Lucretia Mott	suffragette
43	Tc	Barbara Tuchman	author and historian
44	Ru	Ruth	Biblical mother of house of David
45	Rh	Ruth Bader Ginsburg	Supreme Court justice
46	Pd	Phyllis Diller	comedienne
47	Ag	Angela Merkel	German Prime Minister
48	Cd	Elizabeth Cady Stanton	suffragette
49	In	Indira Gandhi	prime minister of India
50	Sn	George Sand	pen name of French writer Lucile Dupin
51	Sb	Susan B. Anthony	US women’s suffrage leader
52	Te	Mother Teresa	nun who ran Calcutta charities
53	I	Queen Isabella	Spanish monarch who funded Columbus
54	Xe	Xanthippe	wife of Socrates

55	Cs	Mary Cassatt	American painter
56	Ba	Clara Barton	founder of American Red Cross
57	La	Lakshmi Bai	led uprising against British rule in India
58	Ce	Celeste Holm	actress
59	Pr	Eva Peron	charismatic First Lady of Argentina
60	Nd	Sarojini Naidu	Indian writer
61	Pm	Madame de Pompadour	mistress of King Louis XV
62	Sm	Margaret Chase Smith	US senator from Maine
63	Eu	Euzhan Palcy	Jamaican film director
64	Gd	Golda Meir	prime minister of Israel
65	Tb	Harriet Tubman	black abolitionist
66	Dy	Sandra Day O’Connor	US Supreme Court justice
67	Ho	Billie Holliday	African-American entertainer
68	Er	Elizabeth Regina (I)	queen of England
69	Tm	Tarquinia Molza	1542-1617 Italian philosopher
70	Yb	Daisy May Bates	Australian anthropologist
71	Lu	Lucrezia Borgia	influential Renaissance noblewoman
72	Hf	Helene Hanff	American author
73	Ta	Tapputi	Ancient Mesopotamian chemist
74	W	Virginia Woolf	British author
75	Re	Mary Lou Retton	gymnast
76	Os	Jacqueline Onassis	former First Lady
77	Ir	Irene of Athens	752-803 Byzantine Empress
78	Pt	Clara Peeters	1594-1657 Flemish painter
79	Au	Jane Austen	British author
80	Hg	Dorothy Hodgkin	Nobel Prize-winning British chemist
81	Tl	Tallulah Bankhead	actress
82	Pb	Pearl S. Buck	author

83	Bi	Hildegard von Bingen	1099-1179 abbess, mystic, and scholar
84	Po	Pocahontas	Native American
85	At	Artemisia of Halicarnassus	ancient Greek ruler
86	Rn	Janet Reno	US Attorney General
87	Fr	Betty Friedan	American feminist
88	Ra	Jeanette Rankin	US Congresswoman
89	Ac	Agatha Christie	British mystery writer
90	Th	Margaret Thatcher	British Prime Minister
91	Pa	Emmeline Pankhurst	British suffragette
92	U	Umm Kulthum	Egyptian singer and musician
93	Np	Flora Nwapa	Nigerian writer
94	Pu	Jane Pauley	American TV reporter
95	Am	Amelia Earhart	aviatrix
96	Cm	Marie Curie	Chemist - Element 96 is named for her
97	Bk	Billie Jean King	tennis star
98	Cf	Charlotte Friend	oncologist and microbiologist
99	Es	Esther	Biblical Jewish queen of Persia
100	Fm	Hanna Fromm	educator
101	Md	Margaret Mead	anthropologist
102	No	Emmy Noether	German mathematician
103	Lr	Laura Ingalls Wilder	author
104	Rf	Jessie Redmon Fauset	African-American author
105	Db	Deborah	Biblical Hebrew judge
106	Sg	Margaret Sanger	founder of Planned Parenthood
107	Bh	Benazir Bhutto	prime minister of Pakistan
108	Hs	Harriet Beecher Stowe	abolitionist author
109	Mt	Lise Meitner	Chemist - Element 109 is named for her
110	Ds	Donna Shalala	HHS Secretary in the Clinton administration

111	Rg	Rose Grymes	NASA astrobiologist
112	Cn	Hillary Clinton	First Lady, Sec. of State, presidential candidate
113	Nh	Wangari Maathai	Nobel Prize-winning Kenyan environmentalist
114	Fl	Florence Nightingale	nurse
115	Mc	Catherine de Medici	1519-1598 married king of France
116	Lv	Anna Pavlova	Russian ballet dancer
117	Ts	Marianna Tessel	engineer
118	Og	Jane Goodall	primatologist

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“It is my earnest desire that some of you should carry on this scientific work and keep for your ambition the determination to make a permanent contribution to science.”

—Marie Curie