The Periodic Table as a Mnemonic Device for Writing Electronic Configurations

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Introduction

Over the past fifty years, numerous mnemonics for writing electronic configurations have been described in the literature *(1–21)*. These useful learning devices have included memory sequences *(1)*, two-dimensional schemes *(2–16)* including the standard periodic table *(17)*, and three-dimensional objects *(18–21)*. As there are 21 published mnemonics, thirteen of which are unique *(1, 2, 11–21)*, one might believe that writing electronic configurations is extremely challenging. Rieck *(22)* argues that students have less difficulty writing the configurations than they do understanding its purpose. Of all of the mnemonics, only Eichinger's *(16)* and Garofalo's *(21)* are accompanied by an explanation for electronic configurations. If the presented mnemonic is devoid of any explanation, then the device becomes another meaningless pattern that inhibits student learning.

This paper presents an interactive method for using the most effective mnemonic for writing electronic configurations, the periodic table *(17, 23)*. The intrinsic relevance of configurations to chemistry will also be discussed briefly by building upon past analogies *(16, 21, 22)*. The activity described here transforms the traditional lecture on atomic structure from being dry, boring, intangible, and irrelevant to becoming engaging, interesting, tangible, and pertinent. Subsequently, students (liberal arts and science majors alike) can write accurate electronic configurations for any element and understand the concept.

This interactive method takes two fifty-minute lecture classes. The first lecture addresses the pertinent background on electronic configurations and the second lecture includes a description of the hands-on method and a demonstration of its use, as discussed below.

Background Lecture on Electronic Configurations

A preliminary lecture focuses on these topics:

- Structure of the extranuclear region (shells, subshells, and orbitals)
- Increase in energy with increasing shell number or subshell type
- Maximum number of electrons per shell or subshell
- Order for filling shells and subshells
- Reason for writing electronic configurations
- Introduction and use of Aufbau diagrams

When first discussing electronic configurations, shell and subshell designations are presented as locations for possibly finding an electron *(16)*. The shell and subshell designations are analogous to either an address used to locate a person or coordinates on a geographical map used to locate cities or streets. Teaching through connections or analogy has been found to promote learning *(24, 25)*.

Rieck *(22)* previously compared an atom to an apartment building, shells to floors in the building, subshells to apartments per floor, and orbitals to rooms in the apartment. The analogy works well for shells and orbitals, where students can easily see the increase in energy from one floor to the next or the similarity in energy for degenerate orbitals with rooms in an apartment. However, the comparison of subshells to apartments on a floor does not work, as there is no visible increase in energy from one apartment, or subshell, to the next except for the increase in apartment number.

Garofalo's analogy of houses on a hill alleviates this problem *(21)*. Individual houses symbolize the principal quantum number *(n)*, floors within each house the second quantum number *(l)*, and rooms on a given floor the third quantum number (m_l). This analogy is vivid and easy to understand, especially if one envisions the Victorian homes at Alamo Square on Postcard Row in San Francisco, CA.

Using the apartment building from Rieck's analogy and the hill from Garofalo's analogy, the new construct becomes apartment buildings or college dormitories on a hill. This picture becomes useful in comparing an electronic configuration to a mailing address. If an electron were to receive mail, the configuration would direct the mail to the most reasonable location for finding a specific electron. Students need to understand that the location of electrons will become important in future discussions on bonding, ground and excited states of atoms, color of compounds, etc.

The Aufbau diagram is then presented and used to write electronic configurations for the first ten elements and a few others. As many textbooks include this technique and many students have used it in high school, this discussion serves as a reasonable starting point.

Preparing for the Activity

Materials for Students

Students need these materials for the exercise:

- A modified periodic table with shell and subshell designations given in each square (Figure 1). Asterisks appear in Figure 1 for elements with an anomaly in their electronic configuration. In a science major's course these irregularities are typically discussed, whereas in a non-science major's course they are not and therefore would not be indicated on Figure 1. For details on how to address these anomalies with ease, see Strong *(17)*.
- A condensed and modified periodic table with the s, d, p, and f subshell regions blocked but only the periods labeled (Figure 2).

- A standard periodic table
- A snack-size plastic bag to contain the candies
- Enough candies to write electronic configurations for the first thirty elements: eight candies of one color to represent s electrons, ten of another color for d electrons, and twelve of a third color for p electrons

Period numbers are indicated on Figures 1 and 2, as comparisons will be made between period numbers and shell numbers. Group numbers are not shown, as they do not aid in the discussion of electronic configurations. Figures 1 and 2 are copied onto separate 8.5" × 11" sheets of paper for each student: see the Supplemental Material for full-size versions.[W]

On separate occasions, candies such as Reese's Pieces, M & Ms, and Choco buttons (a store-brand equivalent) have been used. Since Reese's Pieces come in only three colors, they can be separated for fifty students in just three hours, as opposed to the four hours needed for the other candies. Five or six one-pound bags of candy cost between five to ten dollars. Depending on their size, other flat candies (Skittles or Life Savers), snack foods (different flavored or shaped crackers, or cereals; or a combination of raisins and nuts), or coins can be used. One box of fifty snack-size plastic bags costs less than two dollars.

Materials for Instructor

Instructors need these supplies to model the activity:

- One large, wall-mounted periodic table
- One overhead projector and projection screen
- At least two copies each of Figures 1 and 2 on 8.5" × 11" transparencies
- At least five blank transparencies for recording electronic configurations of selected elements
- At least three different colored overhead markers to draw dots to represent the s, p, and d electrons on Figures 1 and 2

The Periodic Table as a Mnemonic Device

The props are used in the second lecture to help the students envision the periodic table as a mnemonic device for writing electronic configurations. To facilitate this important connection, the act of writing configurations is treated as a game. The winners are those who master this concept.

Initially, Figure 1 is used as the game board. The students lay Figure 1 flat on their desks, while a transparent copy is placed on the overhead projector. Each square of the modi-

Period Number																		
1	1s																	1s
2	2s	2s											2p	2p	2p	2p	2p	2p
3	3s	3s											3p	3p	3p	3p	3p	3p
4	4s	4s	3d	3d	3d	3d*	3d	3d	3d	3d	3d*	3d	4p	4p	4p	4p	4p	4p
5	5s	5s	4d	4d	4d*	4d*	4d	4d*	4d*	4d*	4d*	4d	5p	5p	5p	5p	5p	5p
6	6s	6s	5d	5d	5d	5d	5d	5d	5d	5d*	5d*	5d	6p	6p	6p	6p	6p	6p
7	7s	7s	6d	6d	6d	6d	6d	6d	6d									

6	4f	4f*	4f*	4f*	4f*	4f*	4f	4f*	4f*	4f*	4f*	4f*	4f*	4f
7	5f*	5f	5f	5f	5f*	5f*	5f	5f*	5f*	5f*	5f*	5f*	5f*	5f

Figure 1. Periodic table modified to show shell and subshell designations in each square.

fied periodic table represents a space, with play starting with hydrogen and continuing to the element of interest. Each candy, which represents an electron, is used as a playing piece. From hydrogen to the desired element, one electron is placed into each square according to increasing atomic numbers. As stated above, all s electrons are represented by one color, p a second color, and d a third color. Students place one electron or candy into each square, while a colored dot is drawn into each square on the transparency. Once the appropriate squares are filled, the designations from each square are recorded in the usual format for writing electronic configurations. Using this method, the electronic configurations for the first ten elements and some additional ones are determined. Then comparisons are made between the configurations just recorded and those previously obtained with the Aufbau diagram. The students find that both methods yield the same results. Therefore, Figure 1 is seen as a mnemonic for writing electronic configurations.

Following sufficient practice, all playing pieces are returned to the plastic bag. Then the blocked regions on Figure 2 are compared with the designations in the corresponding areas on Figure 1. Class findings are recorded onto Figure 2, transforming it into Figure 3. For example, most students notice that the first two columns of the periodic table, Groups IA and IIA, correspond to the s subshell. Therefore, the letter "s" is written into the corresponding block on Figure 2. Students also notice that the middle region, the B Group, corresponds to the d subshell; the six rightmost columns, Groups IIIA–VIIIA, to the p subshell; and the bottom two rows, lanthanides and actinides, to the f subshell. The regions are labeled accordingly on Figure 2. Comparisons are also made between the shell number and the period number in the s and p regions of Figure 1. The students recognize that the shell and period numbers are equal. Therefore, "n =" is written beside the words "period number" and an "n" in front of the letters s and p in Figure 2. The shell numbers for the d and f regions are also compared with the period number. Students find that the d region is one less than the period number and the f region two less than the period number. Again all observations are recorded onto Figure 2, resulting in Figure 3.

As the recorded observations are based on patterns, the arrangement of the elements in the periodic table is then discussed. Students compare the electronic configurations for elements within the same group and notice that the elements have similar configurations. Then they are told that configu-

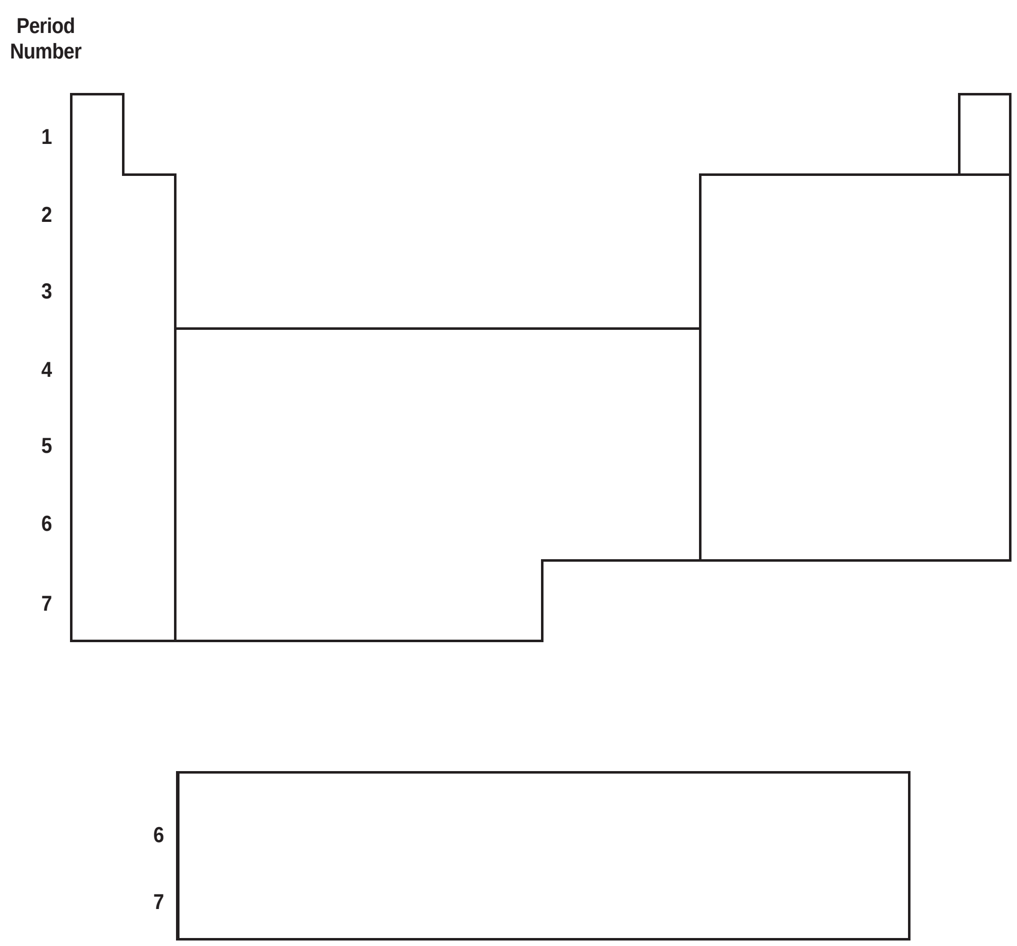

Figure 2. Periodic table condensed and modified to indicate subshell regions.

ration also affects chemical reactivity and bonding, two additional reasons for the arrangement of the periodic table. These similarities will be reinforced later in the course through explicit discussions of bonding and chemical reactivity. By teaching electronic configurations using patterning, the concept becomes meaningful through the organization of shells and subshells. Patterning is one of the twelve principles promoted by Caine, Caine, and Crowell for brain-based learning *(24, 25).*

Figure 3 is then used along with the provided electrons to write electronic configurations for the first ten elements and some random ones. Play again starts with hydrogen, placing one electron per square until the selected element is reached. Comparisons are made among the electronic configurations obtained from the Aufbau diagram, Figure 1, and Figure 3. Students find agreement among the three methods, thus reinforcing the periodic table as an effective mnemonic device for writing electronic configurations.

To emphasize the patterns recorded on Figure 3, the class recites the subshell regions of the periodic table and the relationship of the period number to the shell number for each subshell region. This process helps students commit the patterns to memory for later use. Rehearsal has been shown to be a necessary component in the retention of learning *(26).*

Finally, the standard periodic table and the memorized patterns are used to write electronic configurations for some randomly selected elements. By the end of this class, most students view the periodic table as an effective mnemonic device for writing electronic configurations for any element.

Conclusion

A conventional approach to writing electronic configurations is transformed into an engaging classroom activity using the periodic table as a game board and candies as playing pieces. The candies help students visualize the sometimes elusive, intangible, and esoteric electrons. Since most students are familiar with games and candies, they are more likely to participate in the activity and learn the important chemical concept of electronic configurations. Patterning, rehearsal, and analogy enable students (irrespective of scientific background) to use the periodic table to write electronic configurations and to understand its relevance to chemistry. Students enjoy the candies as an added reward at the end of the class period.

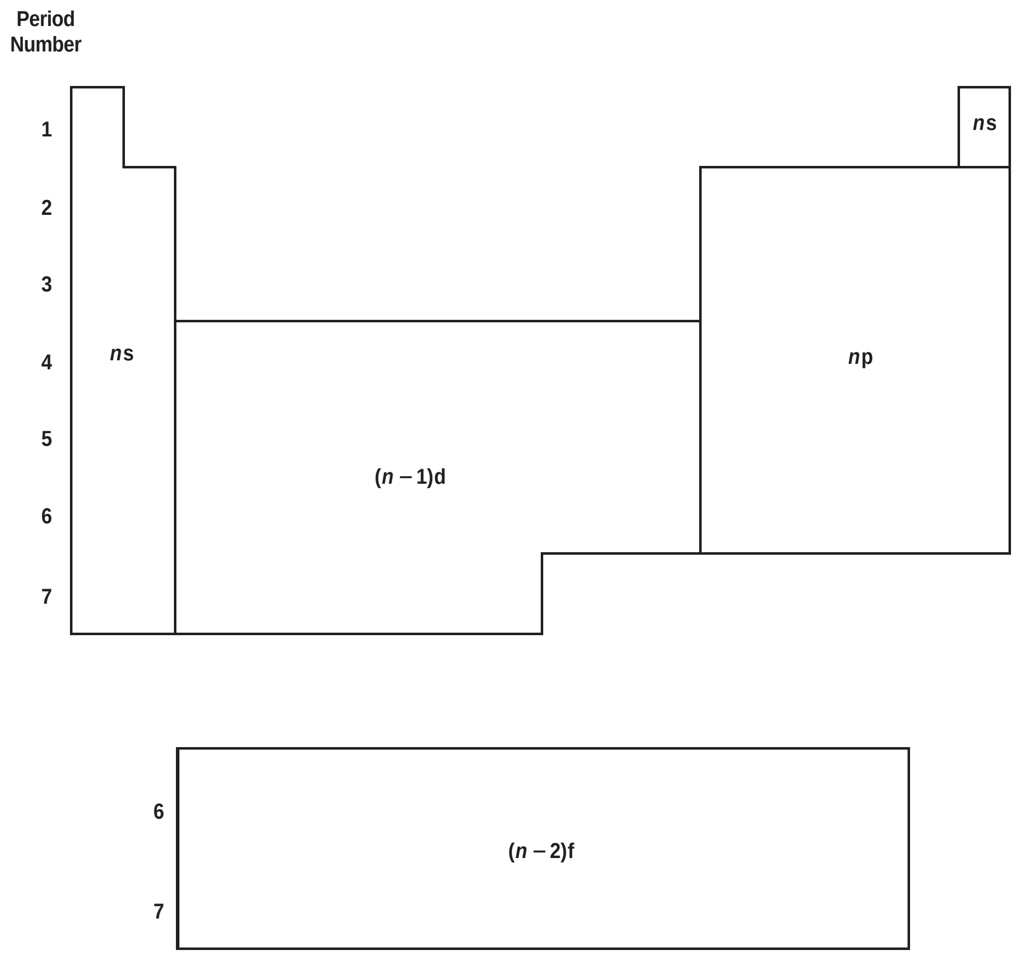

Figure 3. Periodic table modified during the classroom activity to identify the subshell regions.

[W]Supplemental Material

Figures 1 and 2 are available as 8.5" × 11" pages in this issue of *JCE Online*.

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