

Teaching Electron Configuration the Musical Way*

SAM ZHANG

School of Mechanical and Aerospace Engineering, Nanyang Technological University, 50 Nanyang Avenue, Singapore 639798, Republic of Singapore. E-mail: msyzhang@ntu.edu.sg

This paper describes a 'musical way' of teaching the electronic configuration of elements in the periodic table, thus taking the frustration and struggle out of the learning process and making it fun. In essence, the musical notes 'do, re, me, fa, so, la, ti' are denoted by seven digits 1, 2, 3, 4, 5, 6, 7 respectively, to represent the total number of electron energy shells. Sounding out the shell number in music immediately grasps the students' attention and they become instantly involved. The teaching is simple and the learning becomes fun. And hopefully, once learnt, the tune (and thus the electronic configuration) will be remembered for life—thanks to the magic of music.

Keywords: electronic configuration; periodic table; elements.

INTRODUCTION

MATERIALS STUDENTS normally have to learn the full periodic table (Appendix I) and the detailed electron configuration (Appendix II) in the first year of their college life. The sad fact is that this is something they do not naturally like: at first sight, they are just a bunch of numbers mixed with letters. Remembering the sequence and the associated number of electrons is certainly an unimaginable task. My way of teaching it is to create a 'wow' effect first: I ask the class to call out any atomic number (or, better still, the element), then I sound out in music while writing down the electron configuration for that element. 'Wow' the students exclaim every time without fail. The interest is thus planted and the desire to find out how to do it is aroused.

THE MUSICAL WAY

First, define the musical note in seven digits. This is extremely simple. Students from a Chinese background do not have to learn this, because they have all learned the 'simplified musical note' in primary school. For students of other origins, a definition (Fig. 1(a)) may be necessary: view these 'digitized' musical notes ('do, re, me, fa, so, la, ti' for 1 through 7) as the primary quantum numbers (the primary shells). Writing down the primary quantum numbers following the Aufbau principle makes a nice piece of music:

$$1223\ 343\ 4545\ 645\ 6756\ 7 \quad (1)$$

Or 'do re re me—me fa me—fa so fa so—la fa so—la ti so la ti', as given in Fig. 1(b). This is step 2.

In step 3, assign an appropriate orbital letter (s, p, d or f subshell) to each of the 'musical notes'. For this purpose, first identify the same shell numbers, noting that they may not be together—as shown in expression (1) for the bold '5's. It is important to show an example at this stage. For instance, assign orbitals to the '5's: affix the s-orbital to the first '5', p to the second '5', d to the third '5' and 'f' to the fourth '5'. As all the '5's are assigned to the orbitals, expression (1) becomes

$$1223\ 343\ 45s\ 45p\ 645d\ 675f6\ 7 \quad (2)$$

It is necessary to stress to the student that *not* all of the shell numbers will use up the orbital letters. For shell number 1, only s will be used. For shell number 2, only s and p are used; the d and f orbitals are not used. When all the shell numbers are assigned orbital letters, expression (1) becomes

$$1s\ 2s\ 2p\ 3s\ 3p\ 4s\ 3d\ 4p5s\ 4d\ 5p\ 6s\ 4f\ 5d\ 6p7s\ 5f\ 6d\ 7p \quad (3)$$

This is Aufbau's building up principle written on one line. Expression (3) is the 'master skeleton' for electron configuration of all the elements in the periodic table.

Step 4, or the final step, is to fill up the electrons in each orbital. It is now time to get the student to focus on the maximum number of electrons each orbital can accommodate: s up to 2; p up to 6; d up to 10; and f up to 14 (as tabulated in Table 1).

Drawing an analogy with a hotel (beds, rooms and floors) always work wonders in explaining the number of electrons the orbital can 'house'. Also, students appreciate having pointed out to them the 'plus 4' rule: 2 plus 4 is 6 (max for p), 6 plus 4 is 10 (max for d); and 10 plus 4 is 14 (max for f).

At this point of time, a quiz is a good idea, to allow the student to digest the information and put the 'music way' to work. For instance, complete

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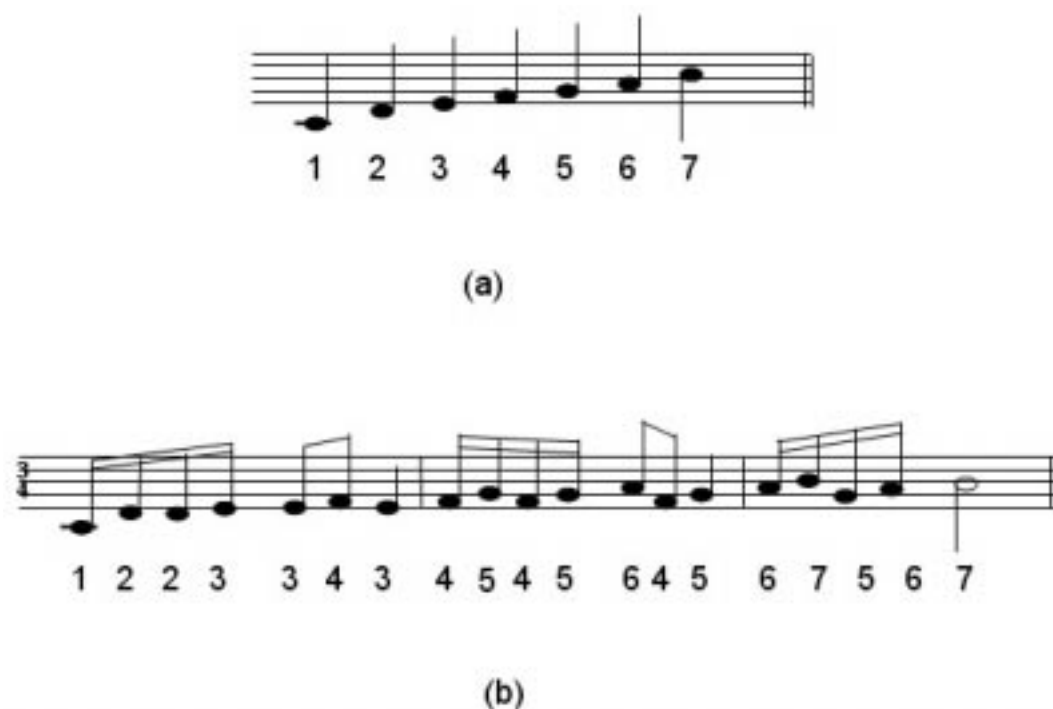


Fig. 1. The musical way: (a) digitizing the basic musical note: 'do re me fa so la ti' as numbers 1 through 7, (b) electron shell arrangements in music 'do re re me—me fa me—fa so fa so—la fa so—la ti so la ti'.

Table 1. Maximum number of electrons the orbitals can accommodate

Orbit	s	p	d	f
Max. no. of electrons	2	6	10	14

the electron configuration of ${}_{32}\text{Ge}$. The answer should be $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$.

Finally, it is necessary to note the few exceptions in filling up the orbital: in some elements, the electrons do not completely fill up the second last orbitals before moving on to fill up the outermost orbital. These elements are Cr, Cu, Nb, Pd, Ce, Tb, Pa and Bk [1]. For instance: ${}_{24}\text{Cr}$: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 \mathbf{3d}^5$ or ${}_{29}\text{Cu}$: $1s^2 2s^2 2p^6 3s^2 3p^6 \mathbf{4s}^1 \mathbf{3d}^{10}$. The irregularity of the number of the electrons is highlighted in bold. These exceptions do not affect the 'music way' nor the assignment of the orbital letters.

SUMMARY

The electron configuration of elements can be taught in a musical way:

Step 1: 'Digitize' the basic musical notes 'do re me fa so la ti' as numbers 1 through 7

Step 2: Sound out in music the primary shell numbers in the Aufbau building up principle: 1223 343 4545 645 6756 7 or 'do re re me—me fa me—fa so fa so—la fa so—la ti so la ti'

Step 3: Assign appropriate s, p, d, f orbitals to each number: 1s 2s 2p 3s 3p 4s 3d 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p

Step 4: Fill up the orbitals with the number of electrons as superscripts to the orbital letter up to their respective maximum: s up to 2; p up to 6; d up to 10; and f up to 14. Note the few exceptional elements (Cr, Cu, Nb, Pd, Ce, Tb, Pa and Bk) that do not completely fill up the second last orbitals before moving on to fill up the outermost orbitals. All the superscripts must add up to equal the atomic number.

REFERENCES

1. Robert C. Weast, M. J. Astle and W. H. Beyer, *Handbook of Chemistry and Physics*, 66th edition, CRC Press, Inc., Boca Raton, Florida (1986), p. B-4.

APPENDIX I THE MODERN PERIODIC TABLE: A REVIEW

The arrangement of elements in the modern periodic table is based on the electron configuration of atoms. Electron configuration refers to the order in which electrons are arranged around the nucleus of an atom.

PERIODIC TABLE OF THE ELEMENTS

Groups →												17	18					
Periods ↓	1											1	2					
	1	2											1	2				
	3	4											5	6	7	8	9	10
	11	12	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54
	55	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
87	88	89	104	105	106	107	108	109	110	111	112	113						
												* 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						

Fig. 2. The modern period table of elements.

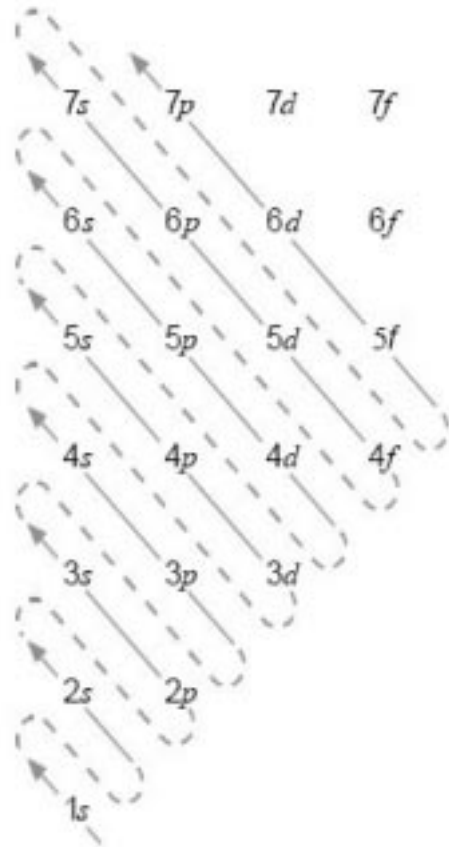


Fig. 3. Aufbau's Building Up Principle.

The periodic table contains rows and columns. The columns are called periods. The rows are called groups. There are 7 periods and 18 groups in the modern periodic table (Fig. 2).

The periods represent the energy levels indicated by the principal quantum numbers 1, 2, 3, 4, 5, 6 and 7. The 18 groups of elements have been classified according to the orbitals (s, p, d and f) because the electrons in these orbitals determine their chemistry. The s-orbital accommodates up to 2 electrons spinning in opposite directions, the p-orbitals up to 6 electrons (3 p-orbitals each can 'house' 2 electrons spinning in opposite directions); the d-orbital up to 10 electrons (5 d-orbitals times 2 each) and the f-orbital 14 electrons (7 orbitals times 2 each).

APPENDIX II THE ELECTRON CONFIGURATION

As electrons fill up the orbitals in an atom, they do so in an effort to minimize the total energy. The energy of an electron depends on the combination of its primary quantum number and the angular momentum; thus 4s is filled up before 3d, etc. Filling of the orbitals follows Aufbau's principle (Fig. 3): the sequence in which the orbitals are filled represents the increasing energy of these orbitals. Spatially, the orbital with the highest principal quantum number is the furthest from the nucleus. The number of electrons of an elemental atom equals the atomic number; thus, given the atomic number of an element, the electron configuration can be written according to Aufbau's building up principle. For instance, Germanium has an atomic number of 32 (i.e. it has 32 electrons), thus the electron configuration of ${}_{32}\text{Ge}$ is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$.

Sam Zhang has been Associate Professor with the School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore, since the turn of the millennium. Dr. Zhang received his Ph.D. degree from the University of Wisconsin-Madison, USA. His subjects include Materials Science, Wafer Fabrication and Advanced Materials Characterization Techniques. His research interests include metallic and ceramic materials, ceramic and bio-ceramic coatings with emphasis on processing methodologies, characterization of properties and industrial applications. Dr. Zhang also serves as Principal Editor for the *Journal of Materials Research*. Details of his teaching and research can be accessed through <http://www.ntu.edu.sg/home/msyzhang>.