「名家讲坛」

用音乐教学电子排布

张善勇

哈尔滨工业大学 航天学院
黑龙江　哈尔滨　150001

摘要：本文描述了一个用音乐方法教学元素周期表的电子排布顺序，将痛苦的死记硬背变成了欢乐的音乐。简谱中 1234567 正好对应电子排布层数，7 是最高层。元素周期表上所有的电子排布都是这些数字的组合，把它们看成简谱的音乐符号变成可以演唱演奏的曲谱。好玩又好记，一旦学会，终身不忘。

关键词：电子排布顺序；元素周期表；元素
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INTRODUCTION

Students of chemistry and materials 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 ······ (1)

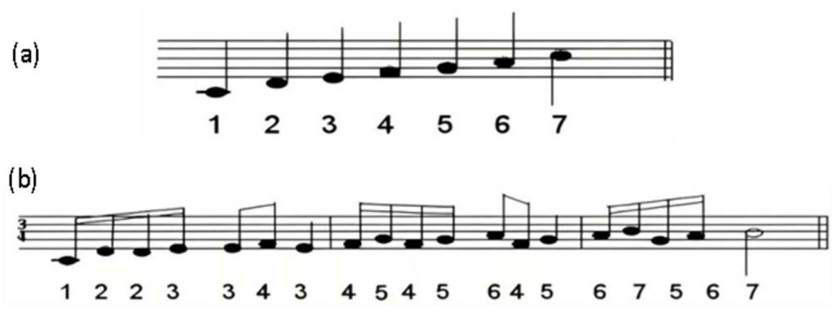

Fig. 1. The musical way: (a) digitizing the basic musical note: "do re me fa so la ti" as numbers 1 through 7, (b) electron shell arrangements in music 'do re re me—me fa me—fa so fa so—la fa so—la ti so la ti'.

通讯作者：张善勇　**邮箱：**Samzhang@hit.edu.cn
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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 4***5s***4***5p*** 64***5d*** 67***5f***6 7 ·· (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 4p 5s 4d 5p 6s 4f 5d 6p 7s 5f 6d 7p ···················· (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

Table 1 Maximum number of electrons the orbitals can accommodate

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

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 the electron configuration of $_{32}Ge$. 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 Bk①. For instance: $_{24}Cr$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^5$ or $_{29}Cu$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^1\ 3d^{10}$. The irregularity of the number of the electrons is high-lighted 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 super-

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.

B = Solids Hg = Liquids Kr = Gases Pm = Not found in nature

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.00794																	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.581538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6534	29 Cu 63.545	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.504	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 196.56655	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	71 Lu 174.967	72 Hf 178.49	73 Ta 180.94.79	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.56655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.58038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	103 Lr (262)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Rg (272)	112 Cn (277)	113 Uut (277)	114 Uuq (277)	115 Uup (277)	116 Uuh (277)		118 Uuo (277)

57 La 138.9055	58 Ce 140.116	59 Pr 140.50765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04
89 Ac 232.0381	90 Th 232.0381	91 Pa 231.035888	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)

Fig. 2. The modern period table of elements.

scripts must add up to equal the atomic number.

APPENDIX

1. 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.

The periodic table contains rows and columns. The rows are called periods. The columns 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).

2. 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

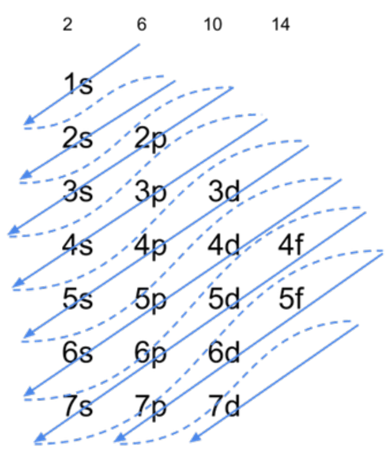

Fig. 3. Aufbau's Building Up Principle

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 $_{32}$Ge is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$.

Teaching Electron Configuration the Musical Way

Sam Zhang

Abstract: 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

作者简介：

张善勇　哈尔滨工业大学航天学院教授、哈尔滨工业大学郑州研究院教授。1991 年获美国威斯康星大学材料学博士学位，1991 年入职新加坡南洋理工大学，先后入选英国材料学会会士（FIoMMM）、英国皇家化学学会会士（FRSC）和国际薄膜学会会士（FTFS、创始人和会长），担任美国 Nanoscience and Nanotechnology Letters 创刊总编 (2008-2015)，Journal of Materials Research 编委，Surface and Coatings Technology 编委。研究硬且韧的红外透明材料，纳米材料硬质薄膜与涂层以及能源薄膜 / 太阳能电池。在 2020-2024 年度连续 5 年入选 World's Top 2% Scientists，在 2024 年“终身科学影响力榜单”Applied Physics 领域全球 304,738 名学者中，张教授位列 492；在 2024 年“年度科学影响力榜单”Applied Physics 领域全球 304,738 名学者中，张教授位列 612。截至 2025 年 6 月 30 日 Web of Science 上收录张教授的文章 428 篇，被引用 14,864 次，H 因子 65。张教授从事薄膜和涂层材料的制备与检测二十多年，著书 / 编书 16 部。其中 14 部由美国 CRC 出版社出版，世界各国国家图书馆和知名大学图书馆均有藏书，譬如英国大不列颠图书馆，美国国会图书馆，中国上海图书馆，首都图书馆，加州理工伯克利图书馆等等......客串编辑科技杂志 10 多卷。其中 2008 年由美国 CRC 出版社出版的《Materials Characterization Techniques》在 2015 年就已经被近 30 所顶尖欧美大学采纳为教材，也被翻译为中文，由中国科学出版社出版发行，该书在中国大学也有很大影响。

后记

本文是 2006 年我在新加坡南洋理工大学机械与航空工程学院做教授的时候受邀在国际工程教育杂志上发表的一篇文章（International Journal of Engineering Education, Vol. 22. No. 5. Page 951-954）。文章发表以后，美国的一个中学老师给我写电邮感谢我的贡献。他让他们班上的乐队把它演奏起来。结果全班一会儿把元素周

期表上所有元素的电子排布顺序全都记住了。我也觉得这个很好玩，很有趣。今见到缪煜清教授主编的科学与艺术结合的杂志，想起这篇差不多20年前的文章，贡献给这个全新的杂志，算是转载吧，重点是表达我的祝贺。

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