Conceptual Understanding of Students on Electron Configuration

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Abstract: Electron configuration is a mnemonic scheme that leads to a deeper understanding of the arrangement of a modern periodic table of elements: the group (family) and period. It also shows valence electron and valence shell; magnetism and pairing of an electron. This study was conducted to determine the level of conceptual understanding of the electron configuration. Conceptual understanding held by the students was based on an open-ended question. The research was carried out with the participation by Grade 9 students. Level of responses, frequencies, and percentage of conceptions held by the students was transcribed and analyzed. Descriptive research was used consisting of one group sample. Results revealed that about 14 (40%) of the students had a full understanding of $4d^6$; about 18 (51.43%) for determining the magnetism of an element; about 14 (40%) in the electron configuration of cation (Fe²⁺) and 30 (85.71%) in an anion (O²⁻); about 31 (88.57%) in the number of paired electron and about 30 (85.71%) in determining the group (family) and period of an element. The students have many misconceptions statements on the electron configuration from ground state to its ion form of an atom. Lastly, students have difficulty in distinguishing the group (or family) and period given only the atomic number. Ergo, various misconceptions in electron configuration were held by the students. It recommended that varied enrichment activities should be given emphasis to minimize or to address misconceptions.

Keywords: conceptual understanding, misconceptions, electron configuration

1. Introduction

General chemistry is commonly perceived to be more difficult than the other subjects. One of the reasons is that chemistry has a very specialized vocabulary; most of the concepts are abstract (Chang, 2010). In spite of chemistry teachers' best efforts in teaching chemistry, learners do not easily grasp the fundamental ideas covered in class (Wandersee, Mintzes and Novak, 2005). Although some smart students give the right answer, they only used correctly memorized words (Blosser, 1987). When questioned more deeply, these students reveal a lack of understanding and fail to explain fully the underlying concepts(National Research Council, 1997). In some research, students are often able to use algorithms and memorized equations and problem-solving skills to solve numerical problems without completely understanding the underlying concepts. Besides offering students information and helpful examples, teachers should show the reasoning processes that lead to algorithms and conceptual generalizations (National Research Council, 1997). Horton (2004) refers to three levels of expressing matter: macro, sub-micro (particle model) and symbolic (chemical notation). They observed that chemistry instruction occurs predominantly on the most abstract level, the symbolic level, and this evidence is ineffective. Locaylocay (2002) cited also that this is because the observed macroscopic properties do not give an indication of what is happening at the microscopic level. Students need to visualize what is happening at the microscopic level.

Students' misconceptions before and after a formal instruction have become a major concern among researchers in science education because they influence how students learn new scientific knowledge. It also plays an essential role in subsequent learning and become a hindrance in acquiring the correct body of knowledge (Özmen, 2004).

Researchers documenting students' alternative conceptions/ or misconceptions about fundamental chemistry concepts. Misconceptions about stoichiometry and balancing chemical reactions, atoms and molecules, electrochemistry, thermodynamics, atomic structure, and chemical bond, and chemical equilibrium have been documented by Horton, 2004 & Kind, 2004.Nakiboglu (2003) has investigated orbitals, hybridization and related concepts by prospective chemistry teachers. Griffiths and Preston (1992) have identified misconceptions related to the fundamental characteristics of atoms and molecules which Grade-12 students hold. Data were obtained by administration of semi structured interviews to a stratified, random sample of 30 students of differing abilities and backgrounds in science.

Posner et al., (1982), in order for conceptual change to take place, it is necessary for students to become dissatisfied with their present conceptions. They also added that a new conception may then be accepted if it seems intelligible and plausible (Posner et al., 1982). It is important to consider ways to take these ideas into account and to develop curriculum materials to promote conceptual change in this domain. Furthermore, one has to understand the cognitive mechanisms responsible for the development of these personal theories and models and why these models are resistant to change (Glynn, Yeany & Britton, 1991). Teachers must develop teaching strategies to promote conceptual change, to lessen misconceptions. Blosser (1987) further cited that teachers should provide more structured opportunities for students to talk through ideas at length, both in small and whole class discussions, begin with known and familiar examples and introduce some science topics into the curriculum at earlier ages.

Many researchers around the world are concerned with finding ways to enable students to change their existing

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conceptions to ones that are likely to be more profitable as they try to the extent their understanding of chemistry (Schmidt, 1994). According to Locaylocay (2004), so as to get optimal insights into the cognitive mechanisms of strategy is to monitor conceptual development throughout the learning process. Such monitoring of conceptual "evolution" provides opportunities for formative assessment and feedback; a powerful, but undervalued teaching strategy (Black, 1998). Studies show that formative assessment produces most learning gains. Tocci and Viehland (1996) cited that the use of technology will help students deepen their understanding underlying the conceptual framework of chemistry to lessen misconceptions and to promote best insights of cognitive level of the students. Using appropriate and relevant materials with the latest and varied teaching strategies gives the students the solid grounding in the basic chemical principles and skills. Furthermore, Tocci and Viehland (1996) cited that instructional goals should develop greater conceptual understanding when students actively participate in the learning process; meaningful learning in their lives and in an environment; and encourages reflection and comparisons with the teachers and peers. These strategies will help the students to focus on mastery of chemistry content and experience scientific inquiry. The use of varied activities such as visualizing and multimedia tools; small-group discussions; and concept mapping has a vital positive outcome to their progression (Necor, 2018). A learning process could be documented and monitored through student worksheets, diagnostic tests, and interview to provide opportunities for formative evaluation and feedback (Locaylocay, 2004).

Misconceptions can be shared by the students wherein some students have the same misconceptions. The National Research Council (1997) suggested that misconceptions can be based on preconceived notions which are rooted in everyday experiences. They also further suggested that nonscientific beliefs such as religious or mythical teachings can cause misconception statements. Conceptual misunderstandings arise when students are taught scientific information in a way that does not provoke them to confront paradoxes and conflicts resulting from their own preconceived notions and nonscientific beliefs. To deal with



Figure 1.0: The Electron Configuration mnemonic. http://ph.images.search.yahoo.com/images/view

their confusion, students construct faulty models that usually are so weak that the students themselves are insecure about the concepts(National Research Council, 1997). Vernacular misconceptions arise from the use of words that mean one thing in everyday life and another in a scientific context (e.g., "work"). And factual misconceptions are falsities often learned at an early age and retained unchallenged into adulthood (National Research Council, 1997).

Before the students embrace the concepts, the science teachers should: identify students' misconceptions; provide a forum for students to confront their misconceptions; and help students reconstruct and internalize their knowledge, based on scientific models (National Research Council, 1997). As further recommended by the National Research Council (1997); science teachers should anticipate the most common misconceptions and be alert. A science teacher must encourage students to test their conceptual frameworks in discussion with other students and by thinking about the evidence and possible tests. Think about how to address common misconceptions as often as you can. And lastly, assess and reassess the validity of student concepts (National Research Council, 1997).

Electron configuration of the atom, that is, how the electrons are distributed among the various atomic orbitals. It describes how the electrons move in an orbital. Mathematically, electron configurations are described by Slater determinants or configuration state functions. Electron configuration is not only all about following the mnemonic scheme as shown in Figure 1.0. Electron configuration can determine if an element is paramagnetic or diamagnetic; elements' number of electron/s from the outermost shell to form cation or anion, and element's group (family) or period. Most students failed to provide an exact definition for an atomic orbital, such as "a one-electron, well-behaved function that can describe - more or less successfully - the behavior of an electron in an atom" (Tsaparliset al., 2002). Thus, this study was pursued to determine the level of understanding of the students from these subtopics of electron configuration and to determine the misconceptions held by the students as basis for remedial activities.



Figure 2.0. The summary of the subshell. http://en.wikipedia.org/wiki/Electron configuration

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2. Objectives of the Study

The objectives of this study is to determine the level of conceptual understanding of the Grade 9 students about electron configuration. It also determined the misconceptions statements in electron configuration by the students.

3. Research Methods

Research Design

This study used a descriptive research design. This was conducted to identify students' level of conceptual understanding in electron configuration as the basis for making remedial activities to address the conceptual understanding. The Grade-9 students were chosen as respondents of the research. All of the respondents were exposed to the same instruction, evaluations and various activities. The respondents took the test immediately after discussing electron configuration. An open-ended test was administered to identify their level of conceptual understanding.

Research Instruments

The research instrument used in the study was an openended questions based on the competencies underlying as shown in Table 1.0. This test was administered to the respondents immediately after teaching electron configuration to identify and to transcribe the level and frequencies of conceptual understanding. A portion of a questionnaire was provided for the respondents to write their solutions or reasoning. Some of the test items were adapted from existing item banks and instruments.

Table 1:	Concept tested	and	answer	on	Electron
	Configura	ation	Test		

No.	Concepts Tested	Correct Concept
1.	Explain the meaning of 4d ⁶ .	The $4d^6$ (read as four d six), 4
		stands for energy level or
		principal quantum number (n); d
		type of orbital and 6 number of
		electrons
2.	Determining the	Element 73 has a set on net
	paramagnetic and	unpaired electron, it is
	diamagnetic of element 73.	paramagnetic.
3.	The electron configuration	$_{26}$ Fe 1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 4s ² 3d ³
	of $_{26}$ Fe and Fe ^{2+.}	$Fe^{2+} 1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^5$
4.	The electron configuration	$_{8}O \ 1s^{2}2s^{2}2p^{4}$
	of $_{8}O$ and O^{2} .	$O^{2-} 1s^2 2s^2 2p^6$
5.	The number of unpaired	$_{29}$ Cu 1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 4s ¹ 3d ¹⁰
	electron in 29Cu.	Therefore, it has one unpaired
		electron in the d orbital.
6.	The period and group	₄₇ Ag
	(family) of 47Ag.	1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 4s ² 3d ¹⁰ 4p ⁶ 5s ² 4d ⁶
		Therefore, Period=5,
		group=11B

Data Gathering Procedure

After discussion of the electron configuration, the respondents took the test immediately. The respondents

were aware about the purpose of the test. All the respondentswere given one hour to finish the test and the instructions were clearly explained before the start of the test. After an hour, all the answers sheets were collected. Respondent's answers were transcribed immediately to assess the level of conceptual understanding based on the criterion of scoring as shown in Table 2.0.

Analysis and Scoring

In analyzing the open-ended questions in the diagnostic test, a concept-evaluation scheme developed in previous research was used in this study (Necor, 2018, Abraham*et al*, 1994; Haidar 1997; and Nakiboglu, 2003). This scheme selected was appropriate for this study because it enabled to score the answer immediately. Student's responses were checked based on the scientific explanations to identify the levels of understanding. Student's answers that condones to the scientific explanation, adjudged as full understanding (FU) and misconception (MU) statement if not. Sometimes, some answers were unclear and blank were adjudged as no understanding (NU).

Tuble 2. The degree of understanding and effective of scoring	Tab	le 2:	The	degree	of	unders	tanding	and	criteria	of	scorin	g
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Degree of Understanding	Criteria for Scoring
FU: Full Understanding	-Responses were scientifically correct.
	- Clearly stated and showed the correct
	explanation and solution
MU: Misconception	-Responses have an incorrect
Understanding	explanation
	- Responses have lacking solution.
NU: No Understanding	Non-sense response
	Unclear response
	No response/Blank

The students' responses were then transcribed and analyzed based on the scientific explanation and the degree of understanding was rated. After students' responses had been categorized, frequency distributions were calculated based on percentage (%) responses. There was no attempt to compare the cognitive, age and other variables to the score of the respondents.

4. Results and Discussions

A. Level of Conceptual Understanding

Students' conception before and after a formal instruction have become a major concern among researchers in science education. It influences how students learn new scientific knowledge. It also plays an essential role in subsequent learning and become a hindrance in acquiring the correct body of knowledge (Özmen, 2006). In this study, a test of six questions was administered to Grade-9 students to identify the level of conceptions on electron configuration. The level of conceptual understanding was categorized as full understanding (FU), misconception understanding (MU) and no understanding (NU). Table 3.0 shows the summary of the level of conceptual understanding of students in electron configuration.

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			Full		Misconception		No		al
No.			standing	Understanding		Understanding			
	Concept Tested	(FU)		(MU)		(NU)			
			%	f	%	f	%	f	%
1	Meaning of 4d ⁶ .		40.00	21	60.00	0	0	35	100
2	Determining the paramagnetic and diamagnetic of element 73.		51.43	17	48.57	0	0	35	100
3	The electron configuration of $_{26}$ Fe and Fe ^{2+.}	14	40.00	21	60.00	0	0	35	100
4	The electron configuration of ${}_8O$ and O^{2-} .		85.71	5	14.29	0	0	35	100
5	The number of unpaired electron in 29Cu.		88.57	4	11.43	0	0	35	100
6	The period and group (family) of $_{47}$ Ag.		85.71	5	14.29	0	0	35	100

Table 3: Level of Conceptual Understanding of students in Electron Configuration

Among the six items, items 4, 5 and 6 garnered the highest percentage of full understanding (FU) of 30 (85.71%); 31 (88.57%); and 30 (85.71%) students, respectively. These include in determining the electron configuration of neutral atom and of an anion. Furthermore, the students can determine the group (family) or period of an element given the atomic number of Silver ($_{47}$ Ag) (item #6).Lastly, the students are able to show correctly the number of electron on a shell given the atomic number of Copper ($_{29}$ Cu) (item #5).

In spite of high percentage of FU, there are still misconception statements held by the students as shown in Table 3.0. it revealed that items 1, 2 and 3 garnered many misconception statements. These include the meaning of $4d^6$; the paramagnetic and diamagnetic of an atom and electron configuration of cation.

B. Misconception Understanding (MU)

The following tables presents the different misconception statements held by the students to each items.

Table 4: Student's misconceptions about the meaning of 4d⁶

Question #1	Sample Responses (Verbatim)
What is the	- The "4" signifies its orbital
meaning of	- The "4" is the quantum number
$4d^{6}?$	- The symbol 4d ⁶ has a quantum number of 4
	- The 4d is the orbital and it has an exponent of 6.
	- The 4d ⁶ is an isotope.
	- The meaning of this symbol is that 4d ⁶ is part of
	electron configuration that is not fully filled and
	it's a type of an orbital.
	- The symbol 4d ⁶ is an example of an electron
	configuration.
	- The symbol 4d ⁶ is that, 4 is an integer.
	- The symbol 4d ⁶ is the number of energy.



Figure 5: The definition of the electron configuration (Source: Chang, 2010)

According to Chang (2010), "4" signifies the principal quantum number or the energy level of an atom. It also depicts the distance of an electron from the nucleus. Whereas the "d" denotes for the type of orbital or angular momentum quantum number. And the superscript signifies for the number of electrons in the orbital or subshell. However, student #16 believed that $4d^6$ is a form of isotope

as shown in Figure 6.0. Isotopes of a particular element contains the same number of proton but differ in the number of atomic masses for example: ${}_{92}U^{235}$ and ${}_{92}U^{239}$.

The symbol	4 d' is an instore. "4' is the energy level,
"d' represents	the arbital, and the 6' represents the
suman of	elections in illus araited.

Figure 6: Misconception statement by student no. 16

 Table 5: Students' misconceptions about paramagnetic and diamagnetic element

Question #2	Sample Responses (Verbatim)
An element has	-The symbol at the last is 5d ³ so there are 3
an atomic number	visible electrons at 5 boxes.
of 73, does this	-The last electron configuration of the element
atom occur as	is 7p ³
diamagnetic or	-This element is a paramagnetic because its
paramagnetic?	isotope is $5d^3$.
	-It is paramagnetic because it contains 5
	unpaired electrons.
	-The element is paramagnetic because all the
	boxes are filled.
	-The element is paramagnetic because it has
	positive charge electrons.
	-It is paramagnetic because it does not contain
	net unpaired electrons.
	-It is diamagnetic because it is not completely
	filled.
	-It is paramagnetic because it has +1/2ms
	-Because there are three unpaired spins and
	there are three unpaired electrons.

Students believed if all orbitals were filled by an electron, it is paramagnetic. In the caseatomic number (Z) =73, the electron configuration is $1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^{10}5p^66s^24f^{14}5d^{10}6p^3$, which shows that the $6p^3$ orbital has an incomplete shell.

Chang (2010) explained that paramagnetic substances are those that contain net unpairedspins and are attracted by a magnet. On the other hand, if the electron spins are paired, or antiparallel to each other, the magnetic effects cancel out. Diamagnetic substances do not contain net unpaired spins andare slightly repelled by a magnet (Chang, 2010). Thus, Z=73 is a paramagnetic element because it contains a net unpaired electrons. According to Hund's rule, the spins of unpaired electrons are aligned parallel and this gives these molecules paramagnetic properties (Chang, 2010).

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Figure 6: Misconception statement by student no. 10

Student No. 10 believed that Z=73 is a paramagnetic which is correct. However, the electron configuration mnemonic is already wrong. The atom must end at $6p^3$ not $5d^3$ as shown in Figure 6.0. Thereby, the student No. 16 was not able to correctly write the correct electron configuration scheme for Z=73 element as adjudged as misconception statement.

Table 5: Students' misconceptions about the electron

configuration of grou	nd state (Fe) and cation (Fe)
Question #3	Sample Responses (Verbatim)
What is the correct	- Fe ²⁺ 1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 4s ² 3d ⁴
electron configuration of	- $\operatorname{Fe}^{2+} 1 \operatorname{s}^2 2 \operatorname{s}^2 2 \operatorname{p}^6 3 \operatorname{s}^2 3 \operatorname{p}^6 4 \operatorname{s}^1 3 \operatorname{d}^7$
ground state Fe and Fe ²⁺	- $\operatorname{Fe}^{2+} 1 \operatorname{s}^2 2 \operatorname{s}^2 2 \operatorname{p}^6 3 \operatorname{s}^2 3 \operatorname{p}^6 4 \operatorname{s}^2 3 \operatorname{d}^8$
(cation, Z=26)?	- $\operatorname{Fe}^{2+} 1 \operatorname{s}^2 2 \operatorname{s}^2 2 \operatorname{p}^6 3 \operatorname{s}^2 3 \operatorname{p}^6 4 \operatorname{s}^0 3 \operatorname{d}^{10}$
	- Fe ²⁺ 1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 3d ⁶

Students are able to write correctly the electron configuration of a ground state element but they are seemed confused when an atom became a cation (Figure 7.0). In Figure 7.0 the student had a correct electron configuration of ground state₂₆Fe but failed to show a correct electron configuration if the Fe became cation (Fe²⁺). The correct electron configuration for Fe²⁺, $1s^22s^22p^63s^23p^64s^03d^8$ the two electrons from the 4s orbital was released and added to 3d orbital. Chang (2010) explained that this phenomenon almost happens in elements that are found in the d-block (transition group or family). It is believed that these group or elements tend to excite (jump to higher energy level) and goes back to the lower energy level.

Figure 7: Misconception representation of electron configuration by student no. 4

Table 6: Students' misconceptions about the electron configuration of ground state (O) and anion (O^{2-})

Question #4	Sample Responses (Verbatim)
What is the correct electron configuration of ground state O and its anion. $\Omega^{2}(Z=8)$?	$\begin{array}{r} - \ O^{2-} \ 1s^2 2s^2 2p^2 \\ - \ O^{2-} \ 1s^2 2s^2 2p^4 3s^2 \\ - \ O^{2-} \ 1s^2 2s^0 2p^6 \end{array}$

Chang (2010) suggested that, in anion, the element tends to be an isoelectronic with noble gases to achieve stability of an atom thus forming an anion. Moreover, the element tends to accept or gain electron/s to become an isoelectronic with noble gases. The charge denotes also the number of electron gained or accepted from its outermost shell or valence shell. Figure 8.0 shows that both student 15 and 21 had a wrong representation of the electron configuration of O^2 . The atoms to become isoelectronic with noble gases, they tend to gain an electron. In the case of O^{2-} , the $2p^4$ orbital will gain two electrons to become an isoelectronic with $_{10}Ne$ element. Thus, O^{2-} must have an electron configuration of $1s^22s^22p^6$.

$$80 = 15^{2} 25^{2} 2p^{4}$$

$$0^{2} = 15^{2} 25^{\circ} 2p^{\circ}$$

Animer: $0^{2} = 15^{2} 21^{\circ} 2p^{\circ}$

Figure 8: Misconception statements held by student's no. 15 and 21

Table 7: Students' misconceptions about the unpaired electron in 20Cu

	chectron in 29eu
Question #5	Sample Responses (Verbatim)
How many	- Only one has no pair because in electron
unpaired electron	configuration 3d ⁴ is not fully filled so the
for 29Cu?	wavelength has no pair.
	- It has one unpaired electron because the last
	orbital is only upward, it has no paired and
	unpaired electron.

Chang (2010) explained that copper (Z=29) is a transition metal. Transition metals either have incompletely filled "d" subshells or readily give rise to cations that have incompletely filled "d" subshells. According to Hund's rule, copper, whose electron configuration is [Ar]4s¹3d¹⁰rather than [Ar]4s²3d⁹. The reason for these irregularities is that a slightlygreater stability is associated with completely filled (3d¹⁰) subshells. In general, half-filled and completely filled subshells have extra stability (Chang, 2010).



Figure 9: The Pauli exclusion principle (filling-up) of orbital of Copper atom

Another application of electron configuration is the determination of the group (family) and period of the element without looking the periodic table of elements. Table 8.0 shows three misconception statements in determining the group and period of ${}_{47}$ Ag.

 Table 8: Students' misconceptions about the group (family) and period of 47Ag

Question #6	Sample Responses (Verbatim)					
What is the group	- The last electron configuration of 47Ag is					
(or family) and	$4d^9$, so its period is 4 while its group is 11B.					
period of 47Ag?	- The period is 4 and group is 11B.					
	- The period is 11 and group is 5B.					

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The period denotes the highest principal quantum number while the group can be determined by its number of electron in the valence shell. In the case of ${}_{47}Ag$, the electron configuration is $1s^22s^22p^63s^23p^64s^23d^{10}4p^65s^24d^9$ which means that it is in period 5 and group 11B. Some students

seemed to confuse about the period because according to them, $4d^9$ is last orbital but the $5s^2$ is the highest principal quantum number (5) as shown by student No. 23 in Figure 10.0



Figure 10.0: Misconception representation of student no. 23

Electronic configurations describe electron's orbital, its magnetism of element as paramagnetic or diamagnetic, elements' number of electron/s from the outermost shell to form cation or anion, and can determine the group (family) or period of an element. Based on the results, many students have suggested many misconceptions statements. This results further suggested that chemistry education teachers should be aware the possible misconceptions to be given by their students. Additionally, this will give a hint for teachers to look for possible teaching strategies. As suggested by the National Research Council (1997), prior the students embrace the concepts, the science teachers should identify students' misconceptions; confront their misconceptions; and guide the students to answer based on scientific models. The teacher can also to think of solid evidences to have some possible strategies such as demonstrations and lab work and to reassess the validity of student concepts (National Research Council, 1997).

C. Possible Enrichment Activities in Electron Configuration

In addressing the misconceptions in electron configuration needs various interventions and activities. Many resources suggested various activities and strategies to address the misconceptions of the students. These include the use of varied activities such as visualizing and multimedia tools; small-group discussions; and concept mapping have a vital positive outcome in their progression (Necor, 2018) to address misconceptions. The use of experiments particularly on flame tests. This will explain the ground state and excited state of an atom. Computer assisted activities was also recommended. Let the students browse some websites readily available for them to experience the picture of elements' in excited state. They would be able to pictureout the trends of electron configuration within a group (family) and within the period (n) and concept mapping. Lastly, more activities should instill for the students to practice and master the electron configuration. Ergo, from these activities electron configuration is not only a mnemonic to memorize but rather a vital concept to have an in-depth understanding about the atom.

5. Conclusions

This study was undertaken to identify students' level of conceptual understanding in the electron configuration. Based on students' level of conceptual understanding in the electron configuration, it can be concluded that majority of the sample students have full understanding of the electron configuration of neutral atom and in determining the family (group) and period of an atom. Moreover, most of the students have outright misconceptions especially on the meaning of electron configuration, cations' electron configuration and magnetism of an element. It is then recommended to that teachers should be aware of the existing conceptions of the students. prior to the teaching of electron configuration, teachers should be aware of the existing conceptions. The teachers should use the enrichment activities to improve conceptual understanding in electron configuration. And lastly, to assess conceptual understanding based on the diagnostic test and interview.

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