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THE 1ST YEAR CHEMISTRY UNDERGRADUATE STUDENTS' UNDERSTANDING IN NAMING SIMPLE COMPOUNDS

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ABSTRACT

The aim of this study was to describe the understanding of freshmen majoring in chemistry in naming simple compounds whether simple ionic compounds or covalent compounds. Data were collected from38 students of State University of Malang using a test conducted after they took Basic Chemistry I class. The test was designed in short answer test type in which they had to name the ionic and covalent compounds from their chemical formulas, and vice versa. The result showed that the students' ability in naming several ionic and covalent simple compounds is greatly poor. Naming ionic compounds with polyatomic ions was considered much more difficult for several students. All in all, naming the binary ionic compound that contained metal that formed more than one type of positive ion and thus formed more than one type of ionic compound with a given anion was considered as the most difficult one. It meant that the basic chemistry class that had been took by the 1st year students did not increase their understanding significantly in naming simple compounds. The implication of this study wasthat the teaching strategy in Basic Chemistry I lecture must be optimized in order to increase students' understanding on this topic well.

Keywords: The 1st year chemistry students understanding, naming simple compounds

INTRODUCTION

In considering the characteristic of naming simple compounds that is commonly considered as a factual knowledge in chemistry, the research in this topic including ionic and covalent compounds is far more limited than other topics. Some researchers in science education especially in chemistry education is much more interested in other topics such as the particulate nature of matter, energy, solution and others that are considered contain more conceptual aspects. Harrison &Treagust (2002) emphasized the importance of the particulate nature of matter to be understood by students because this understanding can be used to explain the properties of matter' and the structure of the particles. Indeed, a vast array of biological, chemical and physical phenomena can only be explained by understanding the changes in the arrangement and motions of atoms and molecules. In addition, some researchers such as Treagust, Mocerino, Taber and the others have many publications in microscopic, symbolic and macroscopic levels of chemistry concepts. Meanwhile, Barke, Al Hazari&Yitbarek (2009) collected their research results in identification of students' misconception on Substances and Properties, Particle Concept of Matter, Structure–Property Relationships, Chemical Equilibrium, Acid–Base Reactions, Redox Reactions, Complex Reactions, and Energy. They found the large number of students' misconception on some chemical concepts.

Previous Research in Chemistry Undergraduate Students Understanding

Despite the number of research results focused on the undergraduate students conceptions and understandings in chemistry is not as much as that of on high school students, several publications related to this aspect have been revealed. Sozbilir&Bennet (2007) stated that Interest in children's understanding of science ideas hasits origins in the classic studies of Jean Piaget. Much of the research into students' understanding of chemical ideas has focused on school-age pupils, with less emphasis on undergraduates. The fact showed that many university students even the prospective teachers got difficulties in understanding some fundamental concepts in chemistry as indicated in several research below. Sozbilir&Bennet (2007) found that the majority of the students could not use thermodynamic principles to explain the change in entropy of a system. The students' thinking was found to be poor and limited at a microscopic level. Meanwhile, Carson & Watson (1999) investigated the conceptions held about chemical thermodynamics by first year chemistry undergraduate students. They concluded that students' lack of understanding about work (and lack of any knowledge of pV work) means that it was inevitable that they would have had a limited knowledge of enthalpy at the beginning of the course.

In a more specific purposes, Cartrette&Mayo (2011) investigated the organic chemistry students' understanding and application of acid/base theories in organic chemistry contexts. They knew that most students maintain declarative knowledge rooted in general chemistry training related to acids/bases, but they can't apply it in problem solving tasks. This assertion held true for most participants, whether chemistry majors or pre-professional majors. Further, flaws in student conceptual understanding of acid/base chemistry principles were revealed.Meanwhile, Orgill& Sutherland (2008) identified the Undergraduate Chemistry Students' Perceptions of and Misconceptions about Buffers and Buffer Problems. They conclude that both upper and lower-level chemistry students struggle with understanding the concept of buffers and with solving corresponding buffer problems. While it might be reasonable to expect general chemistry students to struggle with this abstract concept, it is surprising that upper-level students in analytical chemistry and biochemistry continue to struggle even though buffers are taught in many chemistry classes in an undergraduate program.

Boudreaux & Campbell (2012) investigated the students understanding of liquid-vapor phase equilibrium who have enrolled in introductory physics and chemistry courses. Their responses showed thateven after instruction on the relevant material, many students fail to recognize that for one-component systems in which a liquid and its vapor coexist in equilibrium, the pressure is controlled solely by the temperature. Kelly, etc (2010) examined how 21 college-level general chemistry students, who had received instruction that emphasized the symbolic level of ionic equations, explained their submicroscopic-level understanding of precipitation reactions. Students' explanations expressed through drawings and semistructured interviews revealed the nature of the misconceptions that they held. In addition, the research results related to the undergraduate students difficulties in understanding several fundamental concepts in chemistry are widely published by many researchers.

Even more surprising than the first year students' understandings, even the prospective chemistry teachers showed their difficulties in several basic concepts as investigated by several researchers below. Boz (2009) identified thirty-eight prospective chemistry teachers and found that most of them were found to have problems in understanding the neutralization concept, the distinction between strength and concentration of acids and linking the acids and bases topic to daily life. Another study conducted by Sozbilir, etc (2010) involved 67 prospective chemistry teachers at Kazim Karabekir Education Faculty of Ataturk University in Turkey during 2005-2006 academic year and found that the prospective chemistry teachers' got difficulties in determining the differences between the concepts of chemical thermodynamics and kinetics. The analysis of results showed six major misconceptions about the difference between the concepts of chemical thermodynamics and kinetics indicating that the prospective chemistry teachers attempted to interpret the kinetics of several phenomena by using thermodynamics data.

To sum up, based on these research results it can be concluded that students at all grade levels encounter conceptual difficulties even with fundamental chemistry concepts, and they often develop conceptions which differ from those held by the scientific community. Some of these conceptions derive from individuals' direct or indirect observation of, and spontaneous everyday interaction with, thenatural world around them (Driver, Squires, Rushworth, & Wood-Robinson, in Buket & Emine, 2012). Other sources of these conceptions might be textbook misrepresentations, misleading everyday language, and even the act of teaching itself due to inappropriate instructional materials or teachers' own alternative conceptions (Adbo & Taber; Duit & Treagust; Lin, Cheng, & Lawrenz in Buket & Emine, 2012).

Previous Research in Chemical Nomenclature

As stated previously, research results in students understanding in chemical nomenclature especially for simple compounds included ionic and covalent compounds are much more limited. Nevertheless several studies in this topic have been published. A surprising result was found by Habiddin (2011) who has collected several data from the incoming chemistry undergraduate students State University of Malang, class of 2011. He investigated several preconceptions of students in some fundamental concepts in chemistry, one of them is students' abilities in naming simple ionic and covalent compound and vice versa. Many students could not name the simple ionic and covalent compounds from their chemical formulas and vice versa. For example, they name Aluminum(III) hydroxide for $Al(OH)_3$ and write iron(II) oxide and iron oxide for Fe_2O_3.

Some researchers realize the difficulty faced by students in remaining the rules in naming simple compound. Therefore, Morris (2011) used a Card Game to Help Students Learn Chemical Formulas. He stated that for beginning chemistry students, the basic tasks of writing chemical formulas and naming covalent and ionic compounds often pose difficulties and are only sufficiently grasped after extensive practice with homework sets. Therefore, an enjoyable card game that can replace or, at least, complement nomenclature homework sets is described. "Go Chemistry" is similar to the "Go Fish" card game in that students earn points by using cards to correctly form the formulas of covalent and ionic compounds and by subsequently providing the names of these compounds. By playing the game, students practice identifying an element or ion from its chemical symbol, categorizing elements as either metals or nonmetals, determining whether elements will combine to form ionic or covalent compounds, combining the cards in the correct ratio for electrical neutrality for ionic compounds or valency for covalent compounds, and applying the nomenclature rules. The difficulty of the game can be easily adjusted to match the course objectives and the knowledge level of the students.

Another research conducted by Kavak (2012). He suggested thatlearning the symbolic language of chemistry is a difficult task that can be frustrating for students. Therefore, he designed a game, ChemOkey, thatcan help students learn the names and symbols of common ions and their compounds in a fun environment. ChemOkey, a game similar to Rummikub, is played with a set of 106 plastic or wooden tiles. The object of ChemOkey is to create the formulas and names of ionic compounds from tiles on which the names and formulas of common cations and anions are written. With ChemOkey, students can learn the symbols and names of common ions and acquire a level of familiarity with the electroneutrality principle and the names and formulas of ionic compounds.

Understanding Rules in Naming Simple Compounds

In the beginning development of chemistry, there were no systematic rules in naming chemical compounds. Some substances were named based on the name of person who was found them such as Gmelin Compound, Masgnus Salt, Vauquelin Salt and others. The other compounds were named based on their colors such as Prussian Blue. Today, a huge number of chemical compounds have been found, so that a giving name based on the person or the color of certain compounds will bring a big difficulty in recognizing the chemical compounds. To facilitate in recognizing the name and the chemical formula of chemical compounds, IUPAC give the systematic way for naming compounds in which thename tells something about the composition of the compound. The rules are accepted worldwide,facilitating communication among chemists and providing a useful way of labelingan overwhelming variety of substances.

The summarize rules in naming simple compounds are given below. Binary ionic compounds (type I) contain a positive ion (cation) always written first in the formula and a negative ion (anion). In naming these compounds, the following rules apply. A monatomic (meaning "one-atom") cation takes its name from the name of the element. For example, Na^+ is called sodium in the names of compounds containing this ion. A monatomic anion is named by taking the root of the element name and adding-ide. Thus the Cl^- ion is called chloride. Besides, there are many metals (type II) that form more than one type of positive ion and thus form more than one type of ionic compound with a given anion. For example, the compound $FeCl_2$ contains Fe^{2+} ions, and the compound $FeCl_3$ contains Fe^{3+} ions. In a case such as this, the charge on the metal ion must be specified. The systematic names for these two iron compounds are iron(II) chloride and iron(III) chloride, respectively, where the Roman numeral indicates the charge of the cation.The other type of simple compounds is ionic compounds with polyatomic ions such as ammonium nitrate, NH_4NO_3, contains the polyatomic ions $NH_4^+$and NO_3^-. Polyatomicions are assigned special names that must be memorized to name the compoundscontaining them. Lastly, Binary covalent compounds (Type III) are generally formed between two nonmetals. Although these compounds do not contain ions, they are named very similarly to binary ionic compounds.

The Importance of Recognizing Rules in Naming Simple Compounds

Basically, understanding the rules in naming simple ionic and covalent compoundswill facilitate the students understanding at the next concepts. On the other hand, the students' difficulty in recognizing these rules will obstacle their understanding at the next concepts too. For example, in unpublished research Habiddin (2013) found that most students could not solve this problem "If you were to react 10 g of potassium chlorate with excess red phosphorus (P_4), what mass of tetraphosphorusdecaoxide (P_4O_{10}) would be produced?". The main reason for this problem is that they could not write the chemical formula of potassium chlorate properly and write the wrong chemical equation. As a result, they showed an inappropriate result although they understand how to solve a stoichiometric problems in chemistry as well. This result showed that understanding the rule in naming simple compounds is so important in supporting the students' success in their next lecture. Mastering these rules now will prove beneficial almost immediately as we proceed with our study of chemistry.

Goal and Benefit of This Research

This study explored what the first year chemistry undergraduate students of State University of Malang understand and how they implement the rules in naming simple compounds, ionic and covalent compounds. Therefore, the following research question was addressed in this study. "What do chemistry undergraduates students of State University of Malang understand about the rule in naming simple compounds and implement the rule in naming the simple compounds from their chemical formulas and write the chemical formulas of simple compounds from their names?". Thereby, the primary aims of this research are to identify the 1st chemistry undergraduate students' preconception in naming simple compound and to suggest the appropriate teaching learning method of this topic in general chemistry class. These research result provide an applicable solution for the Basic Chemistry lecturers in learning in this topic.

METHOD

Data were collected from 38 students' class 2013 at Chemistry Education Department, Mathematics and Science Faculty UM. The data were collected by a diagnostic test with short answer type. The test was divided into two parts. The first part contains several names of simple compounds in which they have to write the chemical formulas of these compounds correctly. Another parts contains several chemical formulas of simple compounds in which they have to name these compounds correctly.The data were collected after these students have had took the basic chemistry I. the The descriptive research design was used for this study.

RESULT AND DISCUSSION

Research Question Part 1

This part contains several names of simple compounds whether ionic or covalent compounds. The students was asked to write the chemical formulas of these compounds correctly. The problems sample and students' responses were listed in the Table 1 below.

Table 1. Students' responses in naming simple compounds

No.	Chemical Formula	Students Response: Original/English	Number Answered (%)
1.	H_2	Dihidrogen/ dihydrogen	28,95
		Hidrogendioksida/ hydrogen dioxide	2,63
		Hidroksida/ hydroxide	2,63
2.	$AlBr_3$	Aluminiumtribromida/ aluminum tribromide	7,89
		Alumunium (III) bromida/ aluminum (III) bromide	34,21
		Alumuniumbromintrioksida/ aluminum bromine trioxide	2,63
3.	SO_2	Sulfit/ sulfite	10,52
		Monosulfurdioksida/ monosulfur dioxide	2,63
		Belerang (II) oksida/ sulfur (II) oxide	2,63
		Sulfur oksida/ sulfur oxide	5,26
		Sulfide/ sulfide	2,63
		Oksigendioksida/ oxygen dioxide	5,26
		Sulfat/ sulfate	2,63
		Sulfur (IV) oksida/ sulfur (IV) oxide	2,63
		Sulfatdioksida/ sulfate dioxide	2,63
		Disulfioksida	2,63
4.	Na_2S	Dinatriumsulfida/ disodium sulfide	26,32
		Dinatriumsulfat/ disodium sulfate	10,52
		Dinatrium sulfur/ disodium sulfur	5,26
		Natriumsulfat/ sodium sulfate	2,63
		Natriumdisulfida/ sodium disulfide	2,63
		Natrium(II) belerang/ sodium(II) sulfur	2,63
5.	CuCl	Tembagaklorida/ copper chloride	44,73
		Tembaga(II) klorida/ copper (II) chloride	2,63
		Cusiumklorida	2,63

At the question number 1, students were asked to name H_2, one type of covalent simple compound (type III). About 60% of respondents/students gave the correct answer while the other gave the wrong one. The students' who gave the wrong answer were divided into 3 kinds of answers. Two kinds of students answer, **hidrogendioksida and hidroksida**, written by 2,63% of respondents for each kind of answer. Although the number of students given this answer was relatively small, this answer is surprising. The mentioning of **oksida**and **hidroksida**that are associated with the presence of oxygen is inacceptable because there is no oxygen in the formula. This phenomenon showed that the respondents absolutely have no idea in this aspect. The high number of students with about 28,95% wrote**dihidrogen** for this formula. It can be assumed that they implemented on of rules in naming binary covalent compounds, prefixes such as mono, di, tri, tetra, etc are used to denote the numbers of atoms present. Because hydrogen is one of elements that normally occur as diatomic molecules like oxygen, nitrogen, and the halogens (H_2, O_2, N_2, F_2, Cl_2, Br_2, and I_2), the naming of **dihidrogen** for H_2 is not recommended.

In the next number, the students' were asked to name $AlBr_3$ that contains aluminum metal, a kind of metal which only form one type of cation (Al^{3+}). Students' response showed that differentiation between the metals which can only form one type of cation and the other that can form more than one type of cations is still a confusing aspect. it is strengthen with the high number of students' who answered **alumunium (III) bromida**for this formula with 34,21%. This difficulty is supported with the students' responses at the last three numbers. The vast majority of students' named **tembagaklorida**for CuCl while the other wrote **tembaga (II) klorida.** The later kind of answer has a mistake not only in recognizing the charge of Cu but also in giving the space between cu and its oxidation number. The similar case occurred in their responses for Na_2S.

Meanwhile, students' responses for the number 3 are much more surprising for several reasons. Because $SO_2$is a binary covalent compound, the name **Belerang (II) oksida** and **sulfur (IV) oksida**are really surprising. Another reason is that this compound is so familiar for the chemistry students as well as CO_2. The extreme point in this number is the number of students' who named **sulfit** for this compound with more than 10% of respondents meanwhile **sulfat** was wrote as an answer for this formula by 2,63%. It seems that they failed in remaining the rule for some oxyanions occur in series of ions that contain the same central atom and have the same charge, but contain different numbers of oxygen atoms.

Research Question Part 2

This part contains several chemical formulas of simple compounds whether ionic or covalent compounds. The students was asked to name these compounds correctly. The problems sample and students' responses were listed in the Table 2 below.

Table 2. Students' responses in writing the chemical formulas of simple compounds

No.	Chemical Formula	Students Response	Number Answered (%)
1.	Besi(III) sulfat/ Iron(III) sulfate	$Fe_2SO_4^-$	2,63
		$Fe_2SO_4^{2-}$	2,63
		Fe_2SO_3	7,89
		$Fe_2SO_3^-$	2,63
		$Fe_2(SO_4)_2$	5,26
		$Fe_3(SO_4)_2$	2,63
		CuS_3	2,63
		Fe_3SO_4	5,26
		Fe_2S_3	5,26
		Fe_2SO_4	2,63
		$Fe(SO_4)_3$	5,26
		Fe_3S	2,63
		$Fe_3(SO_4)_3$	2,63
		$Fe_3(SO_4)_3^{2-}$	2,63
		FeS_3	2,63
		$Fe(SO_3)_3$	2,63
2.	Dinitrogenpentaoksida/ Dinitrogen pentoxide	N_2O_4	10,52
		$N_2O_4^{2-}$	2,63

3.	Magnesium florida/ MagnesiumFluoride	MgF^+	2,63
		MgFr	2,63
		MgF	18,42
		Mg_2F	2,63
		MgFl	2,63
		Mg_2F	2,63
		Mg_2F^-	2,63
		Mg_2O_4	2,63
4.	Mangan(IV) oksida/ Manganese(IV) oxide	Mn_2O_4	23,68
		MnO_4	10,52
		MnO_4^-	2,63
		MnO_4^{2-}	2,63
		Mn_4O	10,52
		MnO_2^{2-}	2,63
		Mn_2O	2,63
		Mn_4O_2	2,63
		$Mn(O_2)_4$	2,63
5.	Natriumhipoklorit/ sodium hypochlorite	$NaCO_3^-$	5,26
		Na	2,63
		$NaClO^-$	7,89
		$NaHCO_3$	2,63
		$NaPO_4$	2,63
		NaCl	10,52
		NaHClO	2,63
		$NaClO_2$	2,63
		$Na(Cl_5)^-$	2,63
		NaHo	2,63
		$NaHCl_2$	2,63
		$N_2O_5^-$	2,63
		$NaClO_3$	5,26
		$NaClO_4$	2,63
		$NaCl_3$	2,63

At the question number 1, the students, asked to write the chemical formula of **Besi(III) sulfat** correctly. As showed in Table 2, there are so many kinds of students' responses with almost equal number for each kind. The highest one is **Fe_2SO_3** with 7,89% while **Fe_3SO_4**and **Fe_2S_3** were wrote by 5,26% of students' for each answer. Those answers indicate the difficulty faced by students' as showed in the number 2,3,4 and 5 at Table 1.

In the next number, students were asked to write the chemical formula of **dinitrogenpentaoksida** correctly. This compound is a binary covalent compound as same as SO_2 in the part 1. The highest incorrect number in this number is 10,52% for N_2O_4. In this number, the difficulty faced by students' is related to the use of prefix mono, di, tri, tetra, etc. Several students' recognized the prefix penta as 4.

In the last number, students were asked to write the chemical formula of **Natriumhipoklorit**, an ionic compound that contains polyatomic ion. Like the atoms in a molecule, the atoms that make up a polyatomic ion are held together by covalent chemical bonds. The primary barrier for the students' to solve this problem is that polyatomic ions are assigned special names that must be memorized to name the compounds containing them. In addition, **hipoklorit** associated with **klorit**, **klorat** and **perklorat** that must be memorized by them. Even for the **sulfit** and **sulfat**, they could not memorize well. The most surprising answer for this problem is **NaCl**that was choose by 10,52% respondent and considered as the peak. NaCl is so familiar for all chemistry leaners. Therefore this answer is really inacceptable and intolerable for chemistry undergraduate students'.

The students' responses as stated in Table 1 and Table 2 showed thationic compound that contains polyatomic ions is considered much more difficult as showed from the students' responses for number **natriumhipoklorit**. The total number of students' who could not answer this problem correctly is 57,86%. In the mean time naming simple/binary compound (type II) that contains metal that form more than one cationsis considered as the most difficult one. The total number of students' who gave the wrong answer reached about 60.50% and more as showed in number 4 Table 2. This number is not calculated yet for some of students' who did not give an answer for this type of problem. They confused in differentiating whether the metal can only forms one cation or that can forms more than one cation even in differentiating between ionic compounds and covalent compounds.This phenomenon is strengthen with the many kind of students answer for **Na_2S**, **SO_2, besi(III) sulfat** and **natriumhipoklorit**. Besides, they commonly implemented the rule for binary ionic compounds for covalent compounds and vice versa. Another point that can be interpreted from this study is writing the chemical formula from their names is more difficult for students than naming the simple compounds from their chemical formulas. The total number of students' responses in the Table 1 and Table 2 show it.

Implication for Teaching

The results of this study suggest that many students in the first year chemistry undergraduate class have difficulties in understanding the IUPAC nomenclature of simple compounds whether ionic or covalent compounds.After taking basic chemistry class, students' abilities in naming simple compounds did not increase their understanding well. This result showed the similar result in students understanding with the incoming chemistry undergraduate students' as found by Habiddin (2011). The findings of this study may provide some clues about the quality of student learning in typical basic chemistry classes.

This study suggested that students' mastery in naming simple compounds must be assured first before they go to learn the next topics. The understanding in this topic will facilitate their understanding for the next lectures, on the other hand their difficulties in this topic will obstacle their next classes. The consequence of this difficulty has been proved by Habiddin (2013), in which the students' could not solve the stoichiometric problem because of their lack abilities in this topic. The results indicate that a substantial review of teaching strategies at the university level especially in basic chemistry class is essential. The strategies which have been implemented by Morris (2011) and Kavak (2012) can be used especially with the more innovative way. In addition, it is suggested for the lecturers of basic chemistry to give an attention in this aspect.

CONCLUSSION AND SUGGESTION

To sum up everything stated above, the first year chemistry undergraduate students' have difficulties in naming several ionic and covalent simple compounds. Naming ionic compounds with polyatomic ions was considered much more difficult for several students. The possible reason for this difficulty is how to memorize the special names of several polyatomic ions. Meanwhile naming the binary ionic compound that contained metal that formed more than one type of positive ion and thus formed more than one type of ionic compound with a given anion was considered as the most difficult one. They confused in differentiating whether the metal can only forms one cation or that can forms more than one cation even in differentiating between ionic compounds and covalent compounds. It meant that the basic chemistry class that had been took by the 1st year students did not increase their understanding significantly in naming simple compounds. The implication of this study was that the teaching strategy in Basic Chemistry I lecture must be optimized in order to increase students' understanding on this topic well.

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