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Identification of High School Students' Misconceptions on Chemical Bonding With Three Tier Test

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Abstract: Identification of High School Students' Misconceptions on Chemical Bonding With Three Tier Test. This study aims to determine misconceptions among high school students in Medan city on chemical bonding concepts. The research population was 10th grade senior high school students in Medan City, while the samples were taken from 3 schools (school A, B, and C) in Medan City with cluster random sampling technique, a total of 109 students.
Three-Tier Test (TTT) were developed based on indicators that students must master in chemical bonding material. The questions are validated by expert validators so that valid questions are generated. A valid TTT is then given to a sample of students. Furthermore, interviews were conducted with students who experienced misconceptions. All data obtained through the test were processed and analyzed. Results showed students who have misconceptions in high school A, B, and C is 53,33, 41,74, and 54,58 respectively with an average of 48,98%. The misconception occurs largely in ionic bonding(56,58%). In addition, the misconception is also found in the stability elements (51,84%), Lewis symbol and structures (46,18%), and covalent bonding (47,48%)concept. The cause of misconceptions is largely due to the wrong students constructing concepts.
Keywords: Misconception, *Three-Tier Test*, chemical bonding.

Abstrak: Identifikasi Miskonsepsi Siswa SMA pada Ikatan Kimia dengan Test Tiga Tingkat. *Penelitian ini bertujuan untuk mengetahui miskonsepsi siswa SMA di Kota Medan pada materi ikatan kimia. Populasi penelitian adalah siswa SMA kelas X di kota Medan, sedangkan sampel diambil dari 3 SMA (SMA A, B, dan C) di kota Medan dengan teknik cluster random sampling, sebanyak 109 siswa. Tes Tiga Tingkat (TTT) dikembangkan berdasarkan indikator yang harus dikuasai oleh siswa pada materi ikatan kimia. Soal-soal divalidasi oleh validator ahli sehingga didapatkan soal yang valid. TTT diberikan kepada sampel siswa penelitian. Wawancara dilakukan kepada siswa yang mengalami miskonsepsi. Semua data yang didapatkan, selanjutnya diproses dan dianalisis. Hasil penelitian menunjukkan siswa yang mengalami miskonsepsi di SMA A, B, dan C berturut-turut sebesar 53,33, 41,74, dan 54,58 dengan rerata 48,98%. Miskonsepsi sebagian besar terjadi pada konsep ikatan ion (56,58%). Selain itu, miskonsepsi juga ditemukan pada konsep kestabilan unsur (51,84%), lambang dan struktur*

lewis (46,18%), dan ikatan kovalen (47,48%). Sebagian besar miskonsepsi disebabkan oleh kesalahan siswa merekonstruksi konsep.

Kata kunci: *Miskonsepsi, tes tiga tingkat, ikatan kimia*

▪ INTRODUCTION

Students who attend class generally do not have an empty mind, but they have brought some experiences or preconceived ideas when they interact with their environment. The ideas that have been previously owned by students are called preconceptions or alternative conceptions (Pinker, 2003). Students' alternative conceptions are very resistant to change. This new information can be in line with or conflict with students' existing ideas. Students tend to build perceptions and meanings that are consistent with what has been learned previously (Tarigan, 2011). Conceptions created by students can be disparate from the correct concepts according to experts, giving rise to hade concepts called misconceptions (Ikenna, 2015). Misconceptions that occur in students will interfere with students' learning because students cannot learn the next concept if the initial concept they have is wrong. Therefore, identification of students' conceptions is crucial to help students understand concepts correctly and prevent misconceptions in the future.

Students' misconceptions can be identified using several methods, both in writing and through interviews. Methods that can be used to detect misconceptions are multiple-choice tests, concept maps, interviews, and two-tier tests. The Two-Tier Test method is superior to other methods because it is more effective in terms of time, easy to try out, the scoring is more objective, and the results are more accurate for detecting student misconceptions (Akkus et al., 2011). However, this method also has a weakness namely, it cannot distinguish between students who have misconceptions and students who lack knowledge. To overcome this weakness, the Two-Tier Test method can be combined with the Certainty of Response Index (CRI) method developed by Hasan et al. (1999) into the Three-Tier Test (TTT) method.

TTT was used by Gurcay & Gulbas (2015) and was able to identify students' misconceptions about the concepts of heat and temperature. The TTT consists of three levels of statements or questions. The first level is usually in the form of multiple-choice, the second level is the reason for the answers at the first level, and the third level is the student's confidence index for the previous two levels (Peşman & Eryilmaz, 2010). This method can distinguish students who have misconceptions from students who lack knowledge and reduce the percentage of students guessing answers. The interpretation of the results of the TTT can be expanded as done by Sen & Yilmaz (2017).

Chemistry is a science that studies matter and its changes (Chang, 2010). One of the most fundamental subjects in chemistry is chemical bonding (Hanson, 2015). Many of the concepts taught in high school chemistry lessons rely heavily on an understanding of chemical bonding. Most of the concepts in chemical bonding are abstract, making it difficult for students to understand. This will encourage students to make misconceptions about chemical bonding (Tan dan Treagust, 1999). Therefore, it is necessary to identify the misconceptions of chemical bonding with the TTT method to assist students in their learning.

▪ METHOD

This research is descriptive. The research population was all 10th grade high school students in Medan City, while the sample was taken from 10th grade high school students from 3 schools in Medan City. The school sample was selected using a purposive sampling technique based on the school accreditation and curriculum. A total of 3 schools accredited A and using the 2013 curriculum were selected as research samples. Furthermore, one class of 10th grade high school students from each school was taken as a sample using cluster random sampling technique.

The TTT instrument was developed based on indicators that students must master in chemical bonding material. This instrument was validated by an expert validator so that a valid instrument was obtained. The valid TTT instrument consists of 18 objective questions on chemical bonding material. This instrument is used to group students based on their conceptions. Further interviews were conducted with students who experienced misconceptions to obtain more complete data. Based on the results of the misconception test, the samples were grouped into four categories, namely students who knew the concept, did not know the concept, guessed, and experienced misconceptions (Kurniawan, 2018). For clarity, the criteria for this grouping can be seen in Table 1.

Table 1. Category of students' conception

Tier 1	Tier 2	Tier 3(CRI)	Decision
Correct	**Correct**	Sure	Know concept (KC)
Correct	**Correct**	Not sure	Lucky Guess (G)
Correct	Wrong	Sure	Misconception (M)
Correct	Wrong	Not sure	Guess (G)
Wrong	Wrong	Sure	Misconception (M)
Wrong	Wrong	Not sure	Lack of Knowledge (LK)
Wrong	**Correct**	Sure	Misconception (M)
Wrong	**Correct**	Not sure	Guess (G)

Identification of misconceptions is done by dividing the subject of chemical bonding into 4 main indicators spread over 18 items of TTT questions. First, explain the tendency of an element to reach a stable state (questions number 1 and 2). In this section, students are expected to be able to explain how the chemical properties of an element and the tendencies of an element in chemical reactions are described. Second, describe the Lewis symbol and structure (questions numbers 3 to 5). In this section, students are expected to be able to correctly describe the Lewis symbol and structure of an element or compound. Third, explain the process of formation of ionic bonding (questions number 6 to 11). At this stage, students are expected to be able to determine the bonds formed between elements and explain the process of forming ionic bonding. Fourth, explain the process of forming single, double, triple, and coordinate covalent bonding (questions number 12 to 18). At this stage, students are expected to know about the concept of covalent bonds and explain the process of forming covalent bonding.

▪ RESULT AND DISCUSSION

This study describes the conception of Medan City Senior High School students on chemical bonding material. Students' conceptions are grouped into four, namely knowing the concept, not knowing the concept, guessing, and misconceptions. The schools studied were state high schools in the city of Medan, accredited A, and implementing the 2013 curriculum, namely schools A, B, and C. The number of samples from all schools was 109 students. The test given is a TTT diagnostic test of chemical bonding material which consists of 18 multiple choice questions at two levels. In addition, interviews were also conducted with several students who experienced misconceptions after being given the TTT instrument. Based on the results of the misconception test using the chemical bonding TTT diagnostic test, the percentage of misconceptions in each school was obtained as presented in Table 2.

Table 2. Percentage of students' misconception in chemical bonding

Question	Category	Highschool sample			Total (%)
		A	B	C	
1	**M**	26,67	48,72	67,50	49,54
2	**M**	63,33	25,64	75,00	54,13
3	**M**	30,00	12,82	47,50	30,28
4	**M**	50,00	64,10	72,50	63,30
5	**M**	63,33	28,21	47,50	44,95
6	**M**	60,00	33,33	52,50	47,71
7	**M**	50,00	58,97	62,50	57,80
8	**M**	60,00	82,05	60,00	67,89
9	**M**	40,00	33,33	85,00	54,13
10	**M**	80,00	71,79	72,50	**74,31**
11	**M**	40,00	41,03	32,50	37,61
12	**M**	70,00	38,46	45,00	49,54
13	**M**	66,67	17,95	42,50	40,37
14	**M**	70,00	71,79	65,00	68,81
15	**M**	50,00	35,90	45,00	31,19
16	**M**	40,00	20,51	25,00	27,52
17	**M**	53,33	56,41	42,50	50,46
18	**M**	46,67	10,26	42,50	32,11
Average		**53,33**	**41,74**	**54,58**	**48,98**

Based on Table 2, it can be seen that the average percentage of Medan City High School students who experience misconceptions is 48.98%. The highest percentage of misconceptions occurred in high school C, which was 54.58%, while the lowest occurred in high school B, which was 41.74%. The highest misconception occurs in question number 10 where almost all students experience misconceptions (74,31%).

Question number 10 (Figure 1) aims to determine students' understanding of the process of forming ionic bonds from the atoms of their constituent elements.

The misconception that occurs is that students think that a compound formed between an atom of element A which has two valence electrons and an atom of element B which has five valence electrons is a covalent compound. The actual concept is that element A which has two valence electrons will tend to give up electrons to form A^{2+} ions, while element B will tend to accept three electrons to form B^{3-} ions so that an ionic bonding is formed between A and B atom which has the chemical formula A_3B_2. Another misconception is that students describe the direction of displacement of one electron using full arrows in the process of forming ionic bonding. The actual concept is that the displacement of an electron uses a half arrow like a fishing line, while the transfer of an electron pair uses a full arrow.

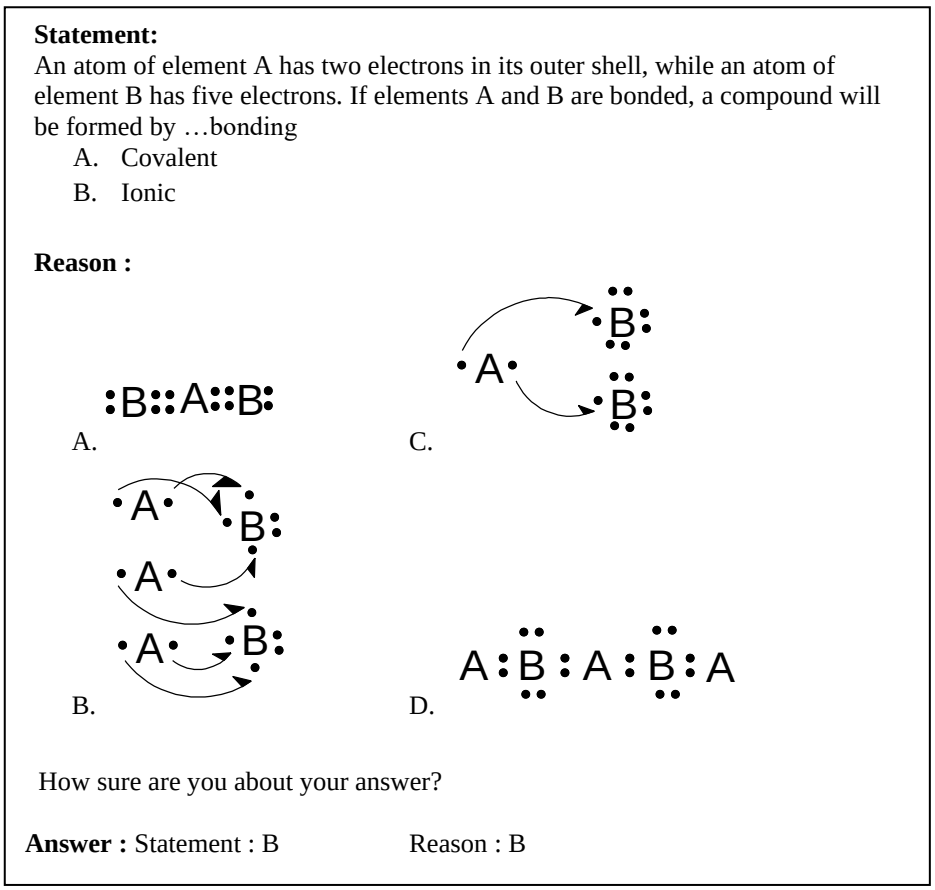

Figure 1. Question number 10

Analysis of Students' Misconceptions on Each Concept

1. **Element stability concept**

   The identification of this concept aims to determine whether students can explain the tendency of an element to reach a stable state correctly. In question number 1, students were asked about the stability of sodium atoms and sodium ions in terms of the number of valence electrons. The identified misconception is that students think sodium atoms are more stable than sodium ions. Students assume the sodium ion has 1 valence electron so it does not qualify the octet

rule. Students already understand the rules of octet and stability but are still confused in determining the number of valence electrons for ions. Students understand that elements that comply with the octet rule are difficult to react with other elements (Fadillah & Salirawati, 2018).

In question number 2, students were asked about whether a molecule can be formed if one of the atoms is not octet. The misconception that occurs is that students assume that all atoms must meet the octet rule for a molecule to be formed. In addition, some students also think that all non-octet molecules are reactive.

2. Lewis symbol and structure concept

Identification of this concept aims to determine whether students can describe the Lewis symbols and structures correctly. In question number 3, students were asked about the Lewis symbol for the nitrogen atom ($_7$N). The misconception that occurs is that students describe the nitrogen atom as having 7 electrons. Students assume the atomic number is the same as the number of electrons. Some students are still confused about the number of electrons and valence electrons. Biswajit (2019) found that none of the students could define valence electrons correctly.

In question number 4, students were asked about the Lewis structure of water (H_2O) and the hydronium ion (H_3O^+). The identified misconception is students assume that there is an ionic bonding in the hydronium ion. Some students think that any charged species must have ionic bonding. This misconception is in line with research by Suyono & Sabtiawan (2019) which found that students were confused about defining ionic bonding.

3. Ionic bonding concept

The identification of this concept aims to determine whether students can explain the concept of ionic bonding correctly. In question number 6, students were asked to explain the type of bond formed between elements $_{38}$X and $_9$Y. The students' misconception is that the type of bond formed is a covalent bonding with the molecular formula XY_2. Students can correctly identify the number of valence electrons of each element but are still confused about the type of bond that occurs.

In question number 8, students are asked to determine the type of bond in sodium chloride (NaCl) and beryllium chloride ($BeCl_2$). The misconception is students assume $BeCl_2$ is an ionic compound. This happens because students are confused about the difference between ionic bonding and covalent bonding. Students think that every compound consisting of metallic and non-metallic elements is an ionic compound (Fahmi and Irhasyuarna, 2017). The difference between ionic and covalent bonding is more emphasized on the difference in electronegativity than the constituent elements (Prodjosantoso et al., 2019).

In question number 7, students were asked about potassium iodide (KI). The students' misconception is the idea that solid KI exists as a molecule. Pérez et al. (2017) found the same thing where students said NaCl is a molecule. Students think that KI is a molecule consisting of K+ and I- ions or K and I atoms. The correct concept is that solid KI exists as a lattice formed of potassium (K+) and iodide (I-) ions (Houscroft & Sharpe, 2005). This misconception is under the

findings reported by Fahmi and Irhasyuarna (2017) who found a misconception of the formation of ionic bonding in NaCl. In question number 9, students were asked about sodium hydride (NaH). The misconception found is that students think that NaH is a metal alloy because the reaction between Na and H is impossible. Students think Na and H are metals because they are in the same group, the alkaline group (1 A).

4. Covalent bonding concept

In question number 12, students were asked about the bonding of the sulfate ion (SO_4^{2-}). Students think that in the sulfate ion there are four single covalent bonding (figure 2. a). Students describe the Lewis structure by adding two electrons to the S atom to form sulfide (S^{2-}) ion before bonding with four oxygen atoms through a single covalent bonding. Another reason students describe the Lewis structure of the sulfate ion like this is so that the central atom (the sulfur atom) obeys the octet rule.

This happens because students generalize the octet rule for all compounds (Pazinato et al., 2021), even though this rule has exceptions The correct concept is that the sulfate ion has two double covalent bonding and two single covalent bonding which always resonance each other (figure 2. b). The sulfate ion applies the expanded octet rule (Houscroft & Sharpe, 2005).

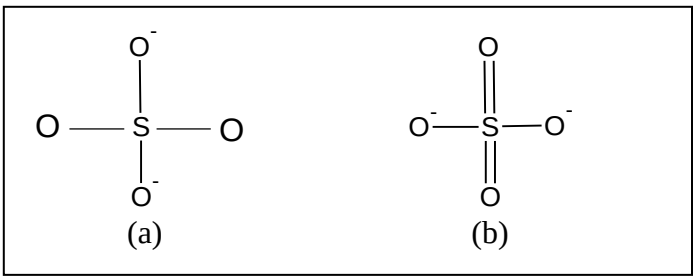

Figure 2. Structure of sulfate ion, (a) student concept; (b) correct concept

▪ CONCLUSION

Most students have misconceptions about chemical bonding. Chemical bonding is abstract so students can construct wrong concepts in their learning. The factors that most influence the occurrence of misconceptions in students are chemistry books and chemistry teachers. Therefore, further research is needed on identifying sources that can cause students to experience misconceptions. If the source of the causes of students' misconceptions has been found, students' misconceptions can be handled as early as possible.

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