The Misconceptions of Senior High School Students in Banjarmasin on Chemical Bonding

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Abstract
This research was conducted to identify the misconceptions of students in SMAN 2, SMAN 3, SMAN 4, SMAN 5, SMAN 7, SMAN 8, and SMAN 13 Banjarmasin on chemical bonding. This study aimed at determining: (1) the percentage of students' misconceptions in each school, (2) the kinds of students' misconceptions in learning the chemical bonds in schools, and (3) the causes of the misconceptions. The present study was a quantitative-qualitative descriptive design survey study. The population of the study was the students of all public senior high schools in Banjarmasin, with seven public senior high schools in Banjarmasin as the sample of the study. This sample was selected based on the status and level of the school. The data of the students' misconceptions were collected by administrating closed-reasoned multiple choice test. An interview was conducted to strengthen the assessment of the misconceptions experienced by students. Based on the results of the study, it was found that the percentage of misconceptions experienced by students in SMAN 2 Banjarmasin was 48.52%, 46.29% in SMAN 3 Banjarmasin, 43.33% in SMAN 4 Banjarmasin, 50.37% in SMAN 5 Banjarmasin, SMAN 7 Banjarmasin 48.15%, SMAN 8 Banjarmasin 39.63% and 48.51% SMAN 13 Banjarmasin. Students had some misconceptions in the sub-concepts of Bonding, Lattice, Intermolecular Forces, and Electrical Conductivity of Graphite. These misconceptions were caused by preconceptions or initial concept of students, the stage of cognitive development of students, and the teacher's explanation.
Keywords: students' misconceptions, preconceptions, alternative concepts, chemical bonds

1. Introdaction

The learning process requires students to integrate the new information with the cognitive structure they had before. It often causes some difficulties for students. Moreover, in some cases, they could not successfully construct the new knowledge they accepted with their prior knowledge to form a complete understanding. It triggers the emergence of different conceptual understandings of students, and causes some misconceptions Fahmi and Irhasyuarna (2017). The incomprehension of students towards a concept can cause some difficulties in learning the more complex and complicated concepts at the next level (Muchtar and Harrizal, 2012).

Chemistry is one of the branches of knowledge containing facts, concepts, laws, theories which were derived from processes and scientific analysis related to the nature, structure, reaction, energy and material changes. Systematically, the concepts in chemistry were related to each other and tend to form the abstract concepts Dhindsa and Treagust (2009) and Unal et al. (2010). An understanding of one of the concepts will be very influential on other concepts. The learning process becomes complicated because every concept must be mastered properly before studying the other concepts.

Generally, chemistry concepts were taught step by step from the easy concept to the more difficult one, from the simple to the more complex concept Taber (2011). One of the fairly complicated concepts in chemistry is the concept of chemical bonding. Before studying the concept of chemical bond, the students must have an understanding on atomic structure, periodic system of elements and the nature and the characteristics of a particular type of atom. So if one of the knowledge chain is lost, students would likely have a difficulty in understanding the whole concept of chemical bonds.

The concept of chemical bonding describes how atoms bond together to form a new molecule. The atoms which are linked to each other and the bonding process occured are often abstract, which is difficult for students to understand it in a whole concept. For example, the students learn that water molecules (H_2O) are the result of bonding between two hydrogen atoms and one oxygen atom. The question arised is that how do we know that there are an atom of hydrogen and two atoms of oxygen, whereas those atoms can not be seen and is difficult to sense by human? Another case in chemical bonding material, for example, students have difficulty in understanding the electron transfer processes in the ion atoms which forms an ionic bond. Dealing with this case, most of chemistry textbooks and teachers in high school level simplifiy and generalize that ionic bonds are formed from metal and non metal atoms, considering students' prior knowledge which in fact would lead to a more complicated problem. Simplification of the formation of ionic bonds with the metal atom of the generalized non-metals would indeed be inclined easily understood students but will damage the cognitive structure Luxford and Bretz (2013) and Vladusic et al. (2016). The difficulty to concrete ionic bonds, in certain cases, causes some difficulties for students to differentiate between ionic bonding with covalent bonds.

The case above is revealed from the researcher's experience during the teaching practice, observation to the school and see the number of students in the material completeness of chemical bonds. The chemistry teacher in SMAN 4 Banjarmasin stated that students' learning outcome in chemical bond is less satisfactory or under the KKM (minimum completeness criteria) set.

One of the vital factors impeding a satisfactory academic achievement is the misconception of students, either due to the preconceptions of students when they try to construct their own concepts in mind or the misconceptions made in school (school made misconception) Barke (2008). The continuing misconceptions will break the system of students' understanding of chemistry as a whole, as majority of the chemistry concepts are related to each other (Nimmermark et al., 2016).

Concepts are essentially constructed from equations of objects, events, or natural phenomena. Imagine if one is unable to classify the events, objects, and activities it encounters in everyday life. Since the stimuli are not consistently true, the person will be forced to respond differently to each stimulus received. This is a very heavy burden for memory.

Humans can categorize various stimuli they felt. Even though there are no two oranges which are exactly the same, we are still able to categorize them and give the same reaction to all members of the class of orange. We can determine its properties, give a name to each category and the same response to all categories by interpreting it, is called the concept (Dahar, 1998).

A concept is the category we give to the stimuli in our environment. Concepts provide organized schemes to assimilate new stimuli, determine relationships within and between them.

Each student has a cognitive structure that is formed based on some experiences and interactions with the environment Fahmi (2016). Before students learn the concepts of chemistry, they have brought a concept as their initial knowledge called preconception. The concept taken and developed autonomously is not always the same as the actual concept suggested by chemists Dhindsa and Treaguest (2009). As they follow the learning process and accept new concepts, they will try to harmonize the new concept with the concept they already have. In this alignment process, there are several possibilities that may occur, including:

(1) The teachers convey the concept incorrectly but the students reconstruct their correct concept;
(2) The teachers convey the concepts correctly but the students did not reconstruct their concept which is actually incorrect;
(3) The teachers convey the concepts correctly, while the students reconstruct their inccorrect concept;

In the first (1) and second (2) cases, the misconception is caused or made by the school (*school made misconception*) and the students themselves. If it is not immediately detected by the teacher, the misconception will continue and be fatal since it will cause an inccorect understanding of the whole chemical concepts. In the third (3) case, the students are already have the idea of constructivism, and it is expected to occur in the learning process (Salirawati, 2010).

Identifying students' misconceptions is the first step to prevent misunderstanding in chemistry learning. The identification of the students' understanding and misconceptions should be done continuously so the core of the problem can be determined and a solution for remediation can be done (Fahmi and Irhasyuarna, 2017).

The results of previous studies indicated the students' misconception during learning Chemical Bonding (Tan and Treaguest, 1999; Dhindsa and Treaguest 2009; Unal et al., 2010; Taber, 2011; Al-Balushi et al., 2012; Pabuccu and Geban 2012; and Nimmermark et al., 2016).

Assumptions and facts mentioned above become the foundation to conduct the present study in order to identify misconceptions of students in chemistry teaching at senior high school level in Banjarmasin, especially in Chemical Bonding for later remediation by teachers so that student learning outcomes can be optimized.

2. Methodology

The method used in this research was a combination between quantitative and qualitative methods and the design of the study was a descriptive survey study, which is research conducted to determine the specific characteristics of a group Fraenkel et al. (2013). In this study, the qualitative method was conducted by interviewing students and chemistry teachers, as well as observing the process of learning. The data collection technique used was purposive sampling. Meanwhile, the quantitative method conducted in this study was characterized by extracting data through a written test instrument of the selected sample then tabulated and presented in percentage form.

The population in this research was all students of tenth grade students of Public Senior High School in Banjarmasin. The sample of research was the students in SMAN 2, SMAN 3, SMAN 4, SMAN 5, SMAN 7, SMAN 8 and SMAN 13 Banjarmasin (seven out of thirteen schools). The subjects were selected based on the consideration of the students' level of knowledge and the quality of each school in Banjarmasin. The researchers consider that the selection of population and sample above can provide accurate data presentation as well as a general description of the extent to which the actual misconceptions in chemistry lessons are experienced especially on chemical bonding.

The data recapitulation of research are done by test and non test tehniques. The test technique is done by giving a series of questions to the students in the form of closed-reason multiple choice, while the non test technique is done by interviewing the students and the teacher. The interview was conducted to the students who could represent the least, moderate, and most numerous error scores on misconception test results.

The data analysis in this research is conducted by using descriptive statistics in the form of percentage so that the raw data could be more readable and more meaningful. After the test on the misconception of chemical bonding was administered, the pattern of student answers were analyzed based on Table 1 below:

Table 1. The Classification of Students Answer

ANSWER COMBINATION	CLASSIFICATION OF STUDENTS' SOLUTIONS
Correct Answer-Correct Reason	Fully Understanding
Incorrect Answer-Correct Reason	Partial Understanding with Misconceptions
Correct Answer-Incorrect Reason	Partial Understanding with Misconceptions
Incorrect Answer-Incorrect Reason	No Understanding

3. Result

The research was started by conducting surveys to several senior high schools in Banjarmasin, interviewing chemistry teachers at school, looking at the classroom learning process and looking at the students' KKM score. The results indicated that in some materials of chemistry, the students have difficulty in understanding the whole concept, especially in the chemical bonding material. This was illustrated by one of the difficulties of students in learning the difference between ionic bonds and covalent bonds. The students have difficulties in understanding the electron transfer process of ion atoms in the formation of ionic bonds. This difficulty makes the students unable to concretize ionic bonds, thus making it difficult for students to distinguish between ionic bonds and covalent bonds which are the basic concepts in chemical bonding material.

The research was done by testing the students to solve the problems in the form of the chemical bonding detection instrument, and interviewing them related to the cause of the misconception. Based on the analysis of the data, the total percentage of students' misconception in seven schools are presented in Figure 1.

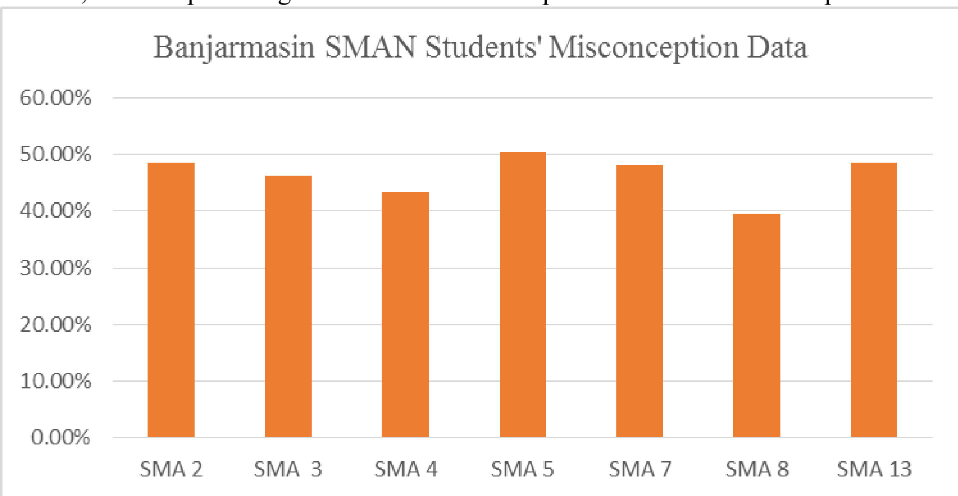

Figure 1. Percentage of students' misconception in Banjarmasin SMAN based on the whole number of students' misconception.

The data were analyzed based on the sub concepts of chemical bond in the misconception detection instrument test. The sub-concepts of chemical bonds are grouped into four main sections as illustrated in Table 2 below.

Table 2. Chemical Bonding Sub Concept based on the number of questions

CONCEPT	SUB CONCEPT
CHEMICAL BONDING	Bonding
	Lattice
	Intermolecular Force
	Electrical Conductivity of Graphite

Evidence of students experiencing misconceptions is when the student selected the correct answer but gave the incorrect reasons, or vice versa as mentioned in Table 1. Then the interview was conducted to find out why the students experienced some misconceptions on chemical bonding, which was analyzed based on the sub concepts of Bonding, Lattice, Intermolecular Forces, and Electrical Conductivity of Graphite.

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4. Discussion

4.1. Bonding

The misconceptions associated with the sub-concept of bonding were caused by preconceptions or prior concepts understood by the students and the incomplete explanation of teachers. It was indicated by students who were not able to distinguish covalent and ionic bonds. There were only few students understood that Sodium Cloride forms an ionic lattice. Students assumed that Sodium ions and Clorida ions form molecular ion pairs that are bonded together to form ionic bonds. Research conducted by Taber (1994); Brick and Kurtz (1999); Tan et al. (2001); Wimmer and Dhindsa (2010); Unal et al. (2010); Luxford and Bretz (2013); and Vladusic et al. (2016) also showed a phrase which was similar to the case above.

The students tended to assume that when the metal and non-metal atoms bonded, it would form an ionic bond. It happened because the teachers often explained with the example of Na^+ and Cl^- without conveying exceptions, so that the constructed understanding of the students was that every metal and non-metal atom was bonded to form an ionic bond. Students also had difficulty in distinguishing between molecules and atoms. According to the information the student gave, the teacher did not give the specific explanation of what constituted the atom and which were the molecules, so they concluded that the molecules bonded together could become the framework of the formation of ionic bonds. This information was obtained from the interview. At the time of interviewing about atoms and molecules, students responded that atoms were similar with molecules because the teacher did not explain the differences between atoms and molecules.

Research conducted by Taber (1994) and Tan (1999) found that the factor influencing the students to show the molecules to became the framework of ionic bond formation was the result of teachers' presentation. In line with that, Dhindsa and Treaguest (2009), in their research, found that the students had some difficulties in understanding the concept of molecules and their differences with atoms. The cause was that the teachers often illustrated ionic bonds by describing the electron transfer from Na atom to Cl atom which formed Na^+ and Cl^- ions. Then, the teacher pointed to a pair of ions and said that the Na ions and the Cl ions were bonded together and attracted with the electrostatic force.

Katsikis et al. (2015) in his research report mentioned that the explanation of teachers tended to make the students' wrong interpretion on the concept of bond formation. Teachers should describe the two main classes of chemical bonds: ionic bonds and covalent bonds, the concepts and concrete examples of both ionic bonds presented in ionic compounds as in the solids of NaCl, MgO, and $BaCl_2$. Covalent bonds are presented in covalent molecules such as H_2O, NH_3, and CH_4 Efendy (2008). The ionic compounds might be in the gas phase, liquid phase and solid phase. The ionic compound in the gas phase comprises ion pairs. The ionic compounds in the liquid phase consist of positive ions and irregularly arranged (randomly) the negative ions. The ionic compounds in the solid phase consist of positive and negative ions arranged regularly, alternately, and repeatedly.

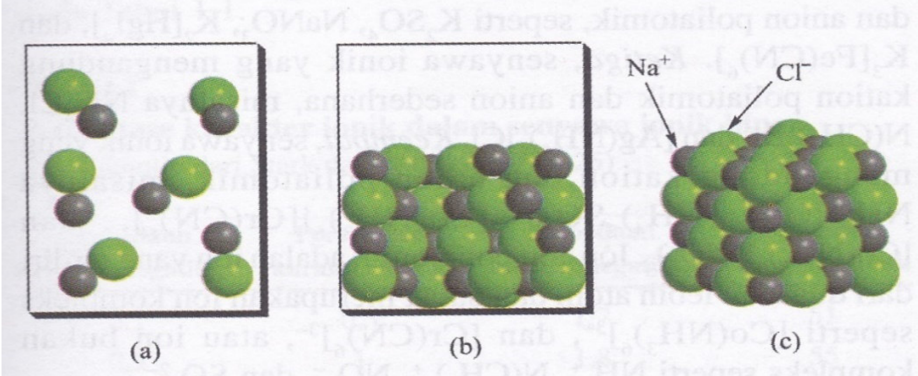

Figure 2. NaCl in phase: (a) a gas consisting of pairs of Na^+ and Cl^- ions; (B) a liquid composed of randomly arranged Na^+ and Cl^- ions; and (c) solids consisting of Na^+ and Cl^- ions which are arranged regularly, alternately and repeatedly (Effendy, 2008)

Figure 2 shows that in the gas phase, NaCl has a simpler structure than NaCl in the liquid phase or solid phase. In general, the results show that the structure of ionic compounds in the gas phase is always simpler than the structure in the liquid phase or solid phase (Effendy, 2008).

Covalent bonds can be defined as forces that cause the same or different sets of atoms bond to be one with the same behavior. It happens because a group of atoms showing the same behavior is more stable or has a lower energy level than the energy level of the atoms in a separate state. For example, the energy level of 1 mole of methane (CH_4) in the gas phase is 1652 kJ lower than 1 mole of carbon atom (C) and 4 moles of hydrogen atom (H) in the gas phase. The bond is shown in the following reaction equation:

$$C_{(g)} + 4H_{(g)} \rightarrow CH_{4(g)} \quad \Delta H = -1652 \text{ kJ/mol}$$

Thus, a CH_4 molecule is more stable than one carbon atom and four hydrogen atoms in the gas phase. In addition, the behavior of C atoms and H atoms in CH_4 is in one unity and different from the behavior of one C atom and one H atom before they form CH_4. Before forming CH_4, the direction of the motion of the C atoms and the H atoms in the gas phase is different, but after forming CH_4, the C atoms and the H atoms have the same direction (Effendy, 2010).

4.2. Lattice

The misconception related to lattice or space (lattice) was caused by students' low cognitive development which made them difficult to understand a concept described by the teacher. In addition, it was also triggered by the simplifications of general and undetailed concepts by the teacher. One of them was shown in the pattern of students' answers, indicating that they could not distinguish the covalent and molecular lattice. The covalent lattice and ionic lattices were often described as having the characteristics of molecule, and the molecular lattice was often depicted as having the characteristics of the covalent lattice. From the pattern of student responses, some of them believed that macromolecules consisted of molecules that are covalently bonded.

Research conducted by Tan and Treagust (1999); Kind (2004); Othman et al. (2008); and Gudyanga and Madambi (2014) presented the same phenomenon in which there was a simplification of concepts in which the teacher gave an explanation of the basic concepts of covalent bonding. After the interview, they found the fact that the students thought that graphite as a substance that was thick because of its' soft and thick texture like a cream. These results were strengthened by the research conducted by Taber (2011), in which the students imagined graphite as a form of thick substance because of the nature of the lubricant in it. Some students experienced a misconception as they assumed that molecules in a simple molecular lattice were formed from 2 to 4 bonded atoms. This misconception was indicated by an understanding that macromolecules or large molecules were formed when smaller molecules were bonded together.

Students did not know that macromolecules could also be formed from atoms that were covalently bonded. Unal et al. (2010) found that students had a misconception on the type or characteristics of atoms forming covalent bonds. Based on the result of an interview, some students stated that macromolecules were the same as complex molecules that bound strongly to the bonds in diamond-forming atoms. They assumed that silicon and graphite were the same. Some students had a misconception on the concept that ionic bonds were stronger than covalent bonds, so they concluded that diamonds were the compounds made up of atoms that were ionically bonded.

The research conducted by Taber (2009) and Nimmermark et al. (2016) revealed that the simplification of concepts by teachers made the less concrete understanding of students. Furthermore, Setiadi and Irhasyuarna (2017), in their study, found that the simplification of concepts and generalizations by teachers tended to undermine the students' cognitive structure. Students' understanding would be well-constructed if they were taught some important things related to a concept so that they could interpret the things they learned. Most students considered that a definition was not very important, but when they lose the keyword of a definition, they would be confused to develop the concept they have.

The students' understanding pertinent to the concept of space lattice was incomplete. They tended to assume that space lattice was the cavity between atoms or ions which then became the space for bonding or reaction, whereas space lattice is the arrangement of dots in a three-dimensional space in which each point has a similar environment, on a side of crystal lattice, the atoms or ions located in the corners of the unit of cell should be the same atoms or ions Effendy (2008). The dots with similar environments are called lattice points. The grid nodes can be arranged in only 14 different arrangements, called the bravais grille. If atoms in a crystal form a regular and repeating arrangement, the atoms in the crystal must be arranged in one of the 14 lattice shapes.

4.3. Intermolecular Forces

The misconceptions found in this discussion were due to the cognitive developmental stages of the student and the explanation of the teacher. It could be seen from the pattern of students' responses in a discussion, showing that they could not identify the characteristics and difference between intermolecular forces and intermolecular forces. During the data collection, the student's responses tended to state that the strong intermolecular force was continuously in the covalent bond lattice. In line with this research, Tan and Treagust (1999); Tarhan et al. (2008); Schmidt et al. (2009) and Cooper et al. (2015) also found the similar result, that was the students did not understand the continuous nature of the covalent lattice and strength on the lattice. The students were less likely to realize that silicon carbide was a macromolecule, they thought that silicon carbide formed a simple molecule with one silicon atom sharing four electrons with one carbon atom. This misconception could lead to an understanding that there was an intermolecular force in silicon carbide that caused its high melting point and boiling point.

The intermolecular force is the electromagnetic force that occurs between molecules or between parts apart from a macromolecule. The force may be a cohesion between similar molecules such as at surface tension, or adhesion between different molecules such as in capillarity. This intermolecular force has attractive tensile characteristics as well as molecular repulses. When two molecules are close together, a repulsive force between the same charge will arise and the higher the rejection energy of Stone (2013). Therefore it would require higher energy which is also used to compress a molecule.

The teachers should give an understanding or lead students to understand that intermolecular forces can occur between; (1) nonpolar molecules with nonpolar molecules; (2) polar molecules with nonpolar molecules; And (3) polar molecules with polar molecules. They could explain it to the students instead of generalizing the concept so that the students'concept is not as complete as the original one.

4.4. Electrical Conductivity of Graphite

The misconceptions of students related to Electrical Conductivity of Graphite were caused by the initial knowledge of students, the stage of cognitive development of students, and explanations from teachers. It was shown from the students' answers which illustrated that they did not understand the concept of electron delocalization in graphite. Most students did not understand that there were only three of the four valence electrons in a carbon atom presented in graphite were involved in the bond. While the fourth electron was not involved, but delocalized in the atomic layer. This is the process which emerged the electrical conductivity of the graphite.

This finding was in line with the results of the study conducted by Tan and Treagust (1999); Smith and Nakhleh (2011); Pabuccu and Geban (2012) and Cooper et al. (2013) who found that the students thought the four electrons of graphite were involved in bonding. There were even some students who assumed the electrical conductivity of the graphite caused by the movement of the atomic layer in graphite. After the learning process, students took some conclusions because they understood that the movement of electrons and ions would generate electricity. Therefore, atomic layers could also conduct an electricity because they were able to move.

Graphite, like diamonds, is an allotrope of carbon, because these two compounds are similar but their atomic structure affects their chemical and physical properties. In graphite, one carbon atom is bonded to three other carbon atoms, but in diamond one carbon atom is bound to four other atoms (Salam et al., 2012).

Graphite consists of a layer of carbon atoms, which can slip easily. Graphite is very soft and can be used as a lubricating oil to make mechanical equipment work more smoothly. Graphite is now commonly used as a "lead" in pencil, and has a grey color. Due to the delocalisation of the interconnected electrons, graphite can act as an electrical conductor.

Misconceptions experienced by students could be solved with a complete explanation by the teacher so they could connect a variety of concepts and knowledge of previous students. If the students could connect various concepts, their memory of the information would also be stronger and was expected to enter long-term memory through meaningful information and some networks of thinking (Fahmi and Irhasyuarna, 2017).

5. Conclusion

Based on the results of the research, it can be concluded that: (1) The percentage of students' misconception in SMAN 2 Banjarmasin was 48.52%, SMAN 3 Banjarmasin was 46.29%, SMAN 4 Banjarmasin was 43.33%, SMAN 5 Banjarmasin was 50.37%, SMAN 7 Banjarmasin was 48.15%, SMAN 8 Banjarmasin was 39.63% and SMAN 13 Banjarmasin was 48.51%. (2) There was a misconception of students in studying chemical bonds on the sub-concepts of Bonding, Lattice, Intermolecular Forces, and Electrical Conductivity of Graphite based on the following data: (a) students could not distinguish specifically between ionic and covalent bonds, as well as molecules and atoms, (b) students could not distinguish between covalent and molecular lattice, as well as the general concept of ionic bonds stronger than covalent bonds, (c) students could not distinguish between intermolecular forces and intermolecular forces, (d) students also did not understand that only three of the four graphite electrons are involved in the bond, whereas one electron is delocalized, causing the graphite to have an electrical charge. (3) The students' misconceptions on chemical bonding materials were caused by preconceptions or prior concepts of students, cognitive developmental stages of students, and the teacher's explanation.

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