

Analysis of Students' Comprehension and Misconception towards the Topic of Salt Solubility

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Abstract

This study aimed to analyze students' comprehension and misconception towards the topic of salt solubility both on the level of microscopic representation and understanding. This study utilized essay diagnostic test as instruments and interviews based on a case study of 10 students in grade 11 at senior high school in Bogor who were given 8 questions regarding salt solubility. The results showed that there was a misconception, 40% of the students misled in drawing microscopically the system of salt and sugar solubility and 50% of the students incorrectly drew the system due to the absence of interaction between salt particle and water, while 10% of the students sketched correctly though it is difficult to notice the result of salt ionization on the solvent. Moreover, 80% of the students were unable to find a link between the alteration system of solvent equilibrium caused by additional salt with various solvents on the macroscopic concept of an insoluble salt equilibrium system and the effect of adding similar ions on the equilibrium system.

Keywords: Misconception, Essay Diagnostic Test, Salt Solubility, Students' Comprehension

INTRODUCTION

Chemistry is a branch of discipline that studies materials in the universe that include changes in matter, interactions and energy related or caused by natural changes (Schaum, 2017; Oxtoby, 2001; Brady, 2000; Flowers, 2015; Megna, 2016). Through chemistry, we recognize the composition of substances and the use of chemicals both natural and artificial; also, we acknowledge the important processes on human being, not to mention our own body. It is an important part of our lives since it can be found in our food, drink, even our emotion and every object that we saw and touched notably by ourselves (Sanjay, 2016; O' Dwyer & Childs, 2012).

Johnstone (1982) divides chemical phenomenon into three levels, namely the real macroscopic level that is visible to the eye, submicroscopic level which is real but cannot be seen directly without a microscope, and symbolic level that contains formulas, chemical equations, graphs and many others.

Learning chemistry, therefore, is necessarily required to students. The learning process itself must be supported by a method that integrates chemistry with the occurrence in the natural environment and the daily lives of the students (Jones et al., 2007;

Jones et al., 2015; Uce, Ceyhan, 2019; Childs, 2015). By doing so, students can construct the knowledge not just limited to understanding the concept but also developing the competence as a whole. (Rahmawati dkk 2017; Taber 2002). Chemistry is not an easy subject to teach and learn both in middle and high level of education (Treagust, 2000; Ozmen & Yildirim, 2005). This is because the curriculum in Indonesia is overloaded; for instance, chemical subject is less associated with daily life. As a result, chemistry becomes abstract and difficult to comprehend. Students tend to memorize chemical concepts in the description of words without being able to explain why and how the process of a substance experiences a reaction (Rahmawati, 2013; Sanchez, 2017).

The source of a problem in teaching chemistry roots on the emphasis of two levels, macroscopic and symbolic. Meanwhile, submicroscopic level is less emphasized; even though the three levels are interconnected as key in learning chemistry (Gilbert and Treagust, 2009; Patil, Swati & Chavan 2019). Another source of a problem is in the method used to teach chemistry as a subject (Sanchez, 2017; Gurel, 2015). For instance, in the light of chemical reactions, teacher usually starts the lesson by defining what a chemical reaction is, and then begins to give

examples of chemical reaction equations that are sometimes not accompanied by an explanation of the application of these reactions in everyday life. Eventually, the teacher immediately gives examples of questions without involving them into experiment in a lab. This will instantly result on the students impression that chemistry lessons are too abstract, and looks as if it is used foreign languages (Nelson, 2002; Eilks and Hofstein, 2015). It is not a surprise seeing students only possesses theoretical comprehension, wider and broader concept of chemical process difficult to achieve. A misconception occurred on this situation (Harrison and Treagust, 2002). Another example in the subject of solubility equilibrium is some teachers prefer to teach about solubility equilibrium limited to facts about salt that is difficult to dissolve (macroscopic) and its chemical reaction equations (symbolic), while for submicroscopic representations of representation are rarely associated. Eventhough the equilibrium of salt solubility is very important to connect submicroscopic presentations with salt compounds (macroscopic) and chemical reactions that occur within it, the students can describe how the distribution of salt particles in a solvent, the interaction between salt particles with its solvents which connects to the

equilibrium system. As a result, knowledge obtained by the students is partial and not comprehensive.

Incomplete student knowledge could merely last for a short time popularly known as a short-term memory (Norris, 2017), in which students succes in solving chemical problem is limited to a memorized algorithm and few is connected to the students' comprehension of the chemical concepts. (Taccetin et al. 2004). Therefore, a possible misconception arised is due to the students' inability to link the three levels of division in chemistry. Sunyono (2011) claims that most learners tend to merely memorize sub-microscopic and symbolic representations that are abstract (in the form of description of words). Consequently, students are unable to imagine the process and structure of a substance undergoing a reaction.

Meanwhile, misconceptions originate from two things namely; experience and learning (Nakiboglu, 2003 in Alawiyah et al 2018; Thompson, 2006; Abell & Lederman, 2007; Chavan & Patankar 2016). Misconceptions occur when students 'understanding of a concept is not in accordance with existing scientific concept (Kirbulut & Geban, 2014); students' initial knowledge forms alternative concept (Barke et al, 2009);

the selection of strategies and learning methods that are not in accordance with the characteristics of the material and the students (Treagust, 1996); and the language of communication used in learning by teachers in delivering material (Barke et al et al, 2009) that is durable and difficult to change (Nicoll, 2001). It can also have fatal consequences because this misunderstanding will link to cognitive knowledge received by the students with subsequent learning. Students will have difficulty in accepting the actual concepts so they may bear a cognitive conflict when learning takes place (Yalcin Unlu, 2014).

Solubility equilibrium is an important topic that can be a fundamental base for students' comprehension regarding other chemical topics such as acid and base behavior, oxidation-reduction reactions, and solubility (Barke et al et al, 2009). Solubility Product Constant is one of the materials that be learned in many concepts (Filiz & Leach, 2007). The study from Ulfah (2016) concluded that 95% of tested concepts were difficult to comprehend. Difficult to understand the concept of solubility and its multiple have a potential to become misconceptions for the subject. Besides, the cause for such misconceptions is the difficulty of students in understanding

terminologically reaction process of the chemical symbols and hard to visualize the abstract chemical reactions (Barke et al et al, 2009).

One way to notice students' misunderstanding is by using a diagnostic test (Fariyani et al., 2015). A good diagnostic test can provide an accurate representation of misunderstanding experienced by the students based on the misinformation they produce. As mentioned above, the purpose of this study is to investigate the level of misunderstanding on the concept of solubility in senior high school students. The concept of solubility equilibrium is an important topic in chemistry because this concept is related to other materials such as solubility, molarity, ions and chemical equilibrium there were several studies concerning the concept of solubility of equilibrium (Chiu et al, 2002; Onder & Geban, 2006).

METHOD

This study aims to analyze students' comprehension and misconceptions of salt solubility material using an Essay Diagnostic Test and interviews that were adapted and developed from Andrés (2001) and Krause and Tasooji (2007). The data had been validated by 5 graduate students of Chemistry Education and 3 senior high school chemistry teachers. There were

10 students grade 11 at senior high school at Bogor as participant in this study. The data collection method is qualitative research. It was done by giving 7 essay questions emphasizing on the concept understanding and materials connection among solubility, equilibrium, reaction rate.

RESULTS AND DISCUSSION

The results of this study are based on 4 essay diagnostic test, namely the concept and macroscopic description of the system of salt solvent and sugar in a beaker (I), the three categorical divisions of solvent equilibrium; soluble salt solutions, saturated, unsaturated and saturated (II), the salt equilibrium system which is difficult to dissolve macroscopically and submicroscopically and symbolically (III), the effect of similar ions in the salt balance system (IV).

The analysis of students' comprehension towards salt solubility is conducted to identify misconceptions experienced by them. The overall average of all items was shown on table 1. In addition, the analysis was carried out in order to compare the consistency of answers related to students' comprehension of three concept categories and it was corroborated by the results of interviews in order to clarify students' answers to the multiple-

choice questions. The analysis results can be seen in Table 1.

Concept of solubility in solvent system

According to the students' answers of the 1st question, it was found that there were 3 types of students' answers. It can be seen from the students' submicroscopic image of salt solvent system in Figure 1, Figure 2, and Figure 3.

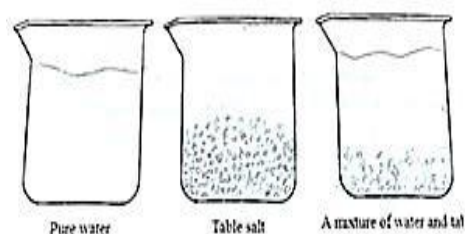


Figure 1. Students' submicroscopic image towards salt solvent

Based on the answer of type 1 in Figure 1, there were 3 students attempted to draw it. 30% of the students were mistaken about the distribution of salt particles in the solvent. It is also clear in the image that as if there is no interaction between NaCl salt particles and water particles in the solvent system. As a result, the salt solids inserted into the solvent settle at the bottom of the glass.

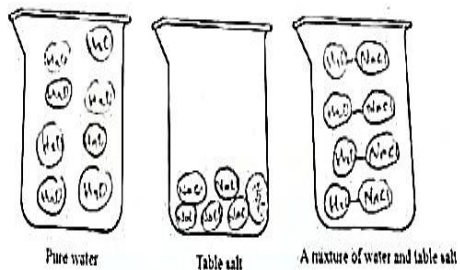


Figure 2. Students' microscopic image towards salt particles on the solvent

Based on the answer of type II in Figure 2, there was an interaction between salt particle and water particle. It can be seen from the circle-draw of NaCl for salt and circle-draw of H₂O for water that were connected each other to a line. However, the distribution of H₂O particles is equal to H₂O, and NaCl is equal to NaCl meaning that between H₂O particles and another one, NaCl and another one is not pulling each other. Pulling each other among particles of NaCl and H₂O is visible on answers type III that is shown in figure 3.

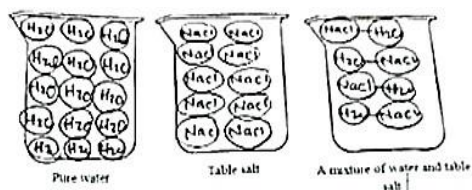


Figure 3. Distribution of H₂O and NaCl particles

Based on the answer of type III in Figure 3, it can be seen the criss-cross distribution particle of H₂O and NaCl; meaning that there is an existence of tugging between one and another. The deficiency of the image above is only at the absence of

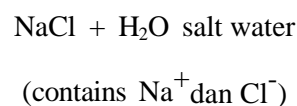
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ionized NaCl distribution that becomes Na⁺ and Cl⁻. In short, from those images students commit mistakes and tend to find difficulty in drawing the particle distribution of solvent system submicroscopically. This findings consistent with Eztok et al (2007) when that students have most problems in representing the particulate level of the solution of the ionic crystal (potassium bromide) and molecular crystals (saccharose) in water.

Reaction of salt on the water

According to the answer of the 2nd question, it was found out that there are 3 types of students' answers in formulating the ion reaction of salt within water (symbolic).

Answer type I (20%):



Based on the answer, students seem to be confused in writing the result product from ionization of NaCl within water.

Answer type II (40%):



Based on the answer, students remain misconceptualized the ionization reaction of NaCl. The correct answer is when the NaCl is dissolved within water, there is an ionization process to become ion Na⁺ and Cl⁻ (Buthelezi, 2008). However, on the interview they claimed that they are

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uncertain for their answers. The following is the sample of the interview.

Interviewer: Is it true or not if NaCl is dissolved on the water, it will form NaOH and HCl?

Student : I guess so.

Interviewer: If yes, when we cook using salt, it will form HCl that is acid and corrosive, so is it still okay to add salt on the food?

Student : *(Students are confused and not completely sure of the answer)*

Answer type III:



Based on the answer, students are correct in formulating the ionization reaction; they just missed to insert the phase of each substance on each reaction.

Saturated, not saturated, and over saturated solvent

Most of students understand the concepts of saturated solvent, unsaturated solvent and saturated solvent as can be drawn from sample of the interview:

Interviewer: Can you describe 3 drawings of saturated, not saturated and over saturated solvent?

Student A : Not saturated, because too many are dissolved, and over saturated because

there is formed a precipitate, and saturated because it is not completely dissolved. This depends on the amount of water and the amount of salt / sugar dissolved.

However, there are a small number of students who look at the type of solvent seen from the points scattered in the image. This can be inferred from this following statement.

Student B : fewer points are said to be saturated, over saturated there are precipitations, and unsaturated, not dissolved and no precipitations.

Students' misconceptions occur in distinguishing saturated, unsaturated and over saturated that is associated with changes in the equilibrium system based on submicroscopic images of the distribution of particles of solute in solution due to addition of solutes. This is also explained by Stephen et al (2013) that students still chose the saturated solution as being supersaturated karena a lack of understanding of the role of solubility limit of solutes in solution.

Salt equilibrium system that is difficult to dissolve

a. The microscopic relationship to AgCl Equilibrium

There was a misunderstanding of equilibrium concept through ionized microscopic-ion on the solvent and on-going reaction equation. This can be

drawn from the following essay diagnostic test and interview:

Interviewer: Which one do you think is easier to dissolved? NaCl or AgCl? Does equilibrium on the AgCl occur in the image?

Student A: There is no equilibrium, because if yes, it will dissolve completely in the solvent and there are substances that settle and dissolve.

Student B : NaCl, there is no equilibrium because it settles, if the equilibrium is present, the solvent does not reach the saturation level. There is no equilibrium between the solvent and the solute so that it cannot be broken down again into the previous substance

From those two answers, students state there is no equilibrium in the AgCl solvent with different reasons. This is due to a misconception of the basic concept of equilibrium of the solution in students.

b. The concept of equilibrium

In the image of AgCl , students were asked to explain how a solvent can be claimed in the state of equilibrium.

Concluded from the data, there is a misunderstanding from the students in

the concept of equilibrium. More than 50% of students assumed that the solvent is said to be equilibrium if the amount of dissolved substances equals to the amount of precipitate formed as discovered on the interview:

Interviewer : Is there an equilibrium on the image? Please explain the reaction?

Student A : Equilibrium refers to the amount of saturated that equals to the amount of sediment

Some students also consider that if the AgCl solution is added to the AgCl solid continuously and not given any treatment, it will not affect the increase in dissolved AgCl and the equilibrium of the solvent. In general there is still an influence on the addition of the concentration of dissolved substances with very little value even though there is no treatment in the solution, this can be seen from the results of student interviews:

Interviewer : Is there a transformation on the solvent if there is an addition of AgCl on the salt solvent although no treatment is done?

Student B : There is no influence although in the long time, no equilibrium on the AgCl solvent.

Table 1. Students' Answers

Concept	No.	Students' Answers	Student (%)
The concept of solubility in systems	1	The macroscopic image of pure water and salt solids is correct, the macroscopic distribution of salt solutions is incorrect	30%
		Macroscopic image of pure water and true salt solids, macroscopic distribution of saline solution is correct but ionized ion is invisible	70%
	3	Macroscopic image of pure water and solids of sugar is correct, no interaction is seen between sugar particles and water in solution	60%
		Macroscopic image of pure water and true solids of sugar is correct, there were visible interactions between sugar particles and water in solution	40%
Salt reaction in water	2	NaCl + H ₂ O salt water (contains Na ⁺ and Cl ⁻)	20%
		NaCl + H ₂ O NaOH + HCl	40%
		NaCl Na ⁺ + Cl ⁻	40%
Saturated solvent, unsaturated and over-saturated	5	Students could connect macroscopic images of the distribution of salt particles in water to saturated, unsaturated and over-saturated solutions but they couldn't connect the changes in the system's equilibrium system due to the addition of salts to the types of solutions (saturated, unsaturated and saturated solutions)	80%
		Students could connect submicroscopic images of the distribution of salt particles in water to saturated, unsaturated and over-saturated solutions and they could connect changes in the equilibrium system of solutions due to the addition of salts to the types of solutions (saturated, unsaturated and saturated solutions)	20%
	7	Students could match correctly the definitions with the terms of solubility	80%
		Students could match incorrectly the definitions with the terms of solubility	20%
The system of salt equilibrium that is difficult to dissolve	8	Students were confused in connecting submicroscopic images with the equilibrium system of AgCl solvent	100%
		Students incorrectly wrote AgCl ionization reaction in AgCl Ag ⁺ + Cl ⁻	60%
		Students were mistaken in terms of the concept of equilibrium in the AgCl solution system "It is said to be balanced if it has the same amount or period so that it has the same concentration."	40%
	4	➤ Students were incorrect in predicting the direction of the equilibrium shift, and did not recognize the effect of shifting the equilibrium towards the product of the salt solubility according to the of Le Chatelier	30%
The effect of similar ions in the salt balance system		➤ Most of students could predict equilibrium shifts when there was an addition of similar ions in solution, but cannot connect the effect of shifting equilibrium toward the product to salt solubility	70%

States that AgCl has complex ions that can cause difficult to dissolve (Silberberg, 2012).

The effect of adding similar ions in the equilibrium system

Lack of student understanding in the addition of AgNO₃ salt in AgCl solvent is suggested to the effect of adding Ag⁺ ions to the equilibrium of the solution. This can be seen from the results of the interview:

Interviewer :Will there be an influence on the solvent if it is added with AgNO₃?

Student A :there won't be an influence because it is using salt and it will be settled on the solvent, no reaction at all on the solvent

Student B :it will form on a new compound due to its diffenes and form a lot if sediment.

The concept for the students to understand about the effect of similar ions on the equilibrium solution is the addition of similar ions to the balance of soluble salts will cause the product concentration ions to increase. Consequently, the equilibrium shifts toward the salt (reactants). In addition, if AgNO₃ is added to the AgCl solvent then there is the addition of Ag⁺ ions on the decomposition of AgNO₃ This yields

in a shift in the equilibrium of the AgCl solvent. Besides, to achieve the equilibrium again the 2 Ag⁺ ions, it will bind to Cl⁻ to form AgCl salts (Buthelezi, 2008).

CONCLUSION

Based on the results of the study it can be concluded that students experience misconceptions on the topic of salt solubility: such (1) on the concept of solubility associated with submicroscopic representation of the solution, students also experience difficulties in connecting between macroscopic, symbolic images and their chemical reactions; (2) in distinguishing between saturated, unsaturated and over saturated solvents that are related to the equilibrium system by the addition of solutes in solvent; (3) misconceptions related to the equilibrium of salts which are difficult to dissolve with submicroscopic levels of the distribution of ions in solvent and the shift in equilibrium due to the effect of adding similar ions in the solute. Misconceptions that are formed on students cannot be said to be wrong because it is an alternative concept by the results of self-development during learning (Barke,2009) so that the teacher is tasked with giving an explanation of the misunderstanding of the concept.

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