Students’ Mental Model on the Chemical Reaction Concept

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Abstract: This study aims to generate profile information of students on the concept of mental models of chemical reactions. The method used is descriptive qualitative. Subjects were 40 high school students in class X in Bandung. The concept of this chemical reaction is limited to reactions that produce gas, temperature changes, discoloration and sediment. Each concept, there are 10 students who analyzed. The collection of data is done using instruments Diagnostic Tests Mental Model-Prediction, Observation, explanation (TDM-POE). The results showed that the concept of reaction that produces gas, 100% of students are able to explain the reaction which produces gas at a symbolic level and level submicroscopic inconsistently. On the concept of reactions that produce changes in temperature, 50% were able to explain the reaction that produces the temperature changes at the level of symbolic and submicroscopic level inconsistently and 50% of students were able to explain the reactions that produce changes in temperature in the symbolic level consistently and inconsistently submicroscopic level. On the concept of reaction that produces a color change, 30% of students are able to explain the reaction that produces a color change on the level of symbolic and level submicroscopic inconsistently and 70% of students are able to explain the reaction that produces a color change on the level of symbolic consistently and level submicroscopic inconsistently. On the concept of reactions that produce precipitate, 80% of students are not able to explain the reactions that produce precipitate either at the level of symbolic and submicroscopic level and 20% of students are able to explain the reaction that produces precipitate at a symbolic level and level submicroscopic inconsistently. Overall it was found that most students have a mental model profiles that are not intact on the concept of chemical reactions. This becomes the input as important information for teachers to improve learning in the classroom.

Keywords: Mental models; TDM-POE; chemical reaction.

1. Introduction

Chemistry learning in the cognitive domain is considered complex because of the chemical includes three levels of representation, ie macroscopic, submicroscopic and symbolic (Wang, 2007, p. 2). Macroscopic level is a real level, and is a phenomenon can be observed in everyday life. Submicroscopic level is also a real level, but at the level of particulates such as describe, explain and make predictions about the properties of chemical substances and the process of how the movement of electrons, particles or atoms. While the symbolic level is the level of representation in the form of models, chemical equations and mathematical equations (Talanquer, 2011, p. 182). When chemists communicate about chemical reactions, so they use a standard way to describe the reaction through chemical equations (Chang, 2005, p. 70). Chemical equation is a statement in the formula that reveals the identity and amount of materials involved in chemical changes or physical changes. (Silberberg, 2007, p. 83). If an experiment has been done, the chemical reaction can mean involve what has happened in the reaction. A chemical reaction is a process in which a substance (or compound) is converted into one or more new compounds. In this material are found difficulty in identifying students every chemical reaction. Chandrasegaran research results (2007, p. 293), there were 14 conceptions are not scientific material chemical reactions. Students are still confused in macroscopic
and submicroscopic representations. This causes the students tend to guess to predict a substance on the submicroscopic level to the macroscopic level, and students also have a limited understanding of the level of symbolic representation.

Profile mental model is an overview of the internal representation of individuals from an object of ideas, thoughts, images, models and other resources that exist in the minds of students to justify, explain, predict, test new ideas and solve a problem (KBBI 2008 & Wiji, 2014, p. 8). Profile students' mental models can be revealed using Diagnostic Tests Mental Model-Prediction, Observation, and explanations (TDM-POE). TDM-POE is a test which not only requires students to memorize the material, but can measure the overall knowledge of the students, by providing the freedom and flexibility in expressing his mental models. Stages TDM-POE is, at this stage of the prediction shown situation or phenomenon, then the students were asked to predict what will happen when something is done the situation and students are asked to give a reason. In the observation phase students describe and write down what they observe. At this stage of explanation students confirm and explain whether there is any difference between predictions with the results of observations (Wang, 2007, p. 32).

As for the formulation of the problem in this research is "What is the profile of mental models students use TDM-POE on the concept of a chemical reaction?". From the formulation of the problem, which is the goal of this study was to determine the profile of students' mental models using TDM-POE on the concept of chemical reactions.

2. Literature Review

2.1. Mental Model

In a book "The Nature Explanation" Kenneth Craik coined the term mental model a person's "small scale model" of external reality and the various actions that possibility in mind, the mental models can help a person to try out various alternatives, conclude which is the best, predict the future situation that has not happened, utilizing knowledge of the events of the past to explain the various terms of the present and the future, and by all means to react much more complete, more secure, and way more competent for the emergencies it faces (Craik, 1943, p. 61). Johnson-Laird (1983, p. 203) developed a theory of mental models based on three basic principles. First, each presents a common mental model of the set of possibilities. Second, mental models are iconic, meaning that the structure of mental models as may be related to the structure presented. Third, mental models are showing what is right and what is wrong leave.

The success of the formation of mental models chemistry students during the learning expected of students are not only able to solve problems that are verbal and mathematical, but also includes the construction of a mental association between the macroscopic level, submicroskopis and symbolic representations of chemical phenomena by using different representations. This makes it possible for teachers to be able to identify the representations that are understood by the students in building mental models so that it becomes meaningful to the students themselves. So the mental model of a person affected by previous knowledge, experience and mastery of the concept. Therefore, a person's mental models may change continuously based on the information he acquired.

2.2. Diagnostic Tests Methods Prediction-Observation-explanatory (TDM-POE)

Diagnostic test is a test used to determine the weaknesses of learners in learning, so that the test results are used as a basis to provide appropriate follow-up and in accordance with the weaknesses of the learners (Depdiknas, 2007). TDM-POE is based on curriculum in 2013 is very suitable as an evaluation tool for students in the learning process for all levels implemented by the scientific approach is called learning the scientific approach. The learning process with a scientific approach carried out by five steps, namely the learning phase to observe, ask, collect data, associate and communicate. There are five steps in the learning stages of TDM-POE, which is when the prediction requires students associate, observation time students observe, ask and collect data. Furthermore, at this stage of explanation students communicate by conveying observations, conclusions based on the analysis and write or tell what is found in the collected data and associated activities.
2.3. Chemical Reaction

When chemists communicate about chemical reactions, so they use a standard way to describe the reaction through chemical equations (Chang, 2004, p. 70). Chemical equation is a statement in the formula that reveals the identity and amount of materials involved in chemical changes or physical changes. The left side of the equation shows the amount of each substance reactants, and the right side shows the number of products or reaction products (Silberberg, 2007, p. 83). If an experiment has been done, the chemical reaction can mean involve what has happened in the reaction. Chemical reactions (chemical reaction), a process in which a substance (or compound) is converted into one or more new compounds.

3. Material & Methodology

The research approach used in this study is a qualitative approach based Fraenkel (2012, p. 429). In this study were not given certain treatments to variable and not design something that is expected to occur in the variable, but all events, situation, events, aspects and components running as it is. Then according to the research focus of the subjects of the study are students of class X semester 2 of academic year 2015 / 2016 on materials chemical reaction in one senior high school in the city of Bandung. Participants involved in this study were 40 students. The data in this study is the result of the analysis of TDM-POE material chemical reaction, before TDM-POE used validated by four lecturers doctoral degree in Chemistry and Education Studies Program is valid. In addition, the test results indicate that the TDM-POE has a good level of legibility problems and easily understood by students.

4. Results and Discussion

Profile mental models of students on the concept of chemical reactions that produce gases expressed using about TDM-POE that requires students to be able to predict what happens when solid calcium carbonate mixed with hydrochloric acid solution, and then observed the phenomenon through video demonstrations, and explain the phenomenon on the level based submicroscopic particles that make up all matter in the reactants and products as well as particles that interact to produce the product. Based on these questions, the profile of mental models appearing on the concept of chemical reactions that produce gases are students able to explain the reaction which produces gas at the level of symbolic and submicroscopic level inconsistently.

![Figure 1. Students Mental Model on Chemical Reaction Concepts Produce Gas](image)

On the concept of reactions that produce gases found 1 pofil students' mental models that students are able to explain the reactions that produce the gas at the level of symbolic and submicroscopic level inconsistently. As can be seen in Figure 1, an example of the students’ answers as much as 30% of students are able to write chemical symbol / formula chemical / molecular formula.
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consistently CaCO3, HCl, H2O, CO2. However, not being able to write chemical symbol / formula chemical / molecular formula CaCl. The inability of students to write the chemical formula is consistent with research Baah (2012, p. 167) reported that the inability of students to write the correct symbol for Barium and inability to write the correct formula for Barium chloride compound. This causes difficulty predicting the correct reaction products because of the inability to write the correct formula (Baah, 2012, p. 169). Students are not able to mention the correct charge each species - species involved in the reaction (Ca+, CO3-, O-). Not able to write particles that interact to produce the product and are not able to write down the net ionic equation. This resulted in students not being able to equalize the reaction and are not able to also demonstrate that the chemical equations obey the law of Lavoisier. Yitbarek (2011, p. 11) argues that in the equation equalizes then they should write down the formula of the reactants and products, and indicates the relative number of particles of each of the reactants and products.

Then for example the students’ answers reactions that produce the gas can be seen in Figure 2. A total of 40% of students are able to write chemical symbol / formula chemical / molecular formula consistently CaCO3, HCl, H2O, CO2. Students are also able to write chemical symbol / formula chemical / molecular formula but inconsistently (CaCl2). Not being able to mention the charge correctly every species - species involved in the reaction (Ca+, CO3-, O-, H2+). Not able to write particles that interact to produce the product and are not able to write down the net ionic equation. The ability of students to write the chemical symbol / formula chemical / molecular formula consistently so as to equalize the equation but were unable to prove that a balanced equation obey the Law Lavoisier. The present invention according to research Hesse (1992, p. 278) in order to explain the chemical changes, students must understand the facts about the properties of chemical substances involved as well as some chemical theory and the most important is the atomic molecular theory.

Write down the chemical symbol / formula chemical / molecular formula

The particles in the reactants and products

Particles that interact to produce a product

Write down the net ionic equation

Chemical equations obey the Law Lavoisier

Examples of students’ answers reactions that produce the gas can then be seen in Figure 3. As many as 30% of students are able to write chemical symbol / formula chemical / molecular formula consistently CaCO3, HCl, H2O, CO2, CaCl2. Not being able to mention the charge correctly every species - species involved in the reaction (Ca+, CO3-, O-). Students are not able to write particles that interact to produce the product and are not able to write down the net ionic equation. Students are able to equalize the equation and be able to prove that the chemical equations obey the Law Lavoisier. The
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inability of students to write particles that make the product according to the invention Ben-Zvi (1982, 1987) that he found the students have difficulty in changing their thinking when they were asked to explain the level of submicroscopic (interactions between atoms and molecules) although it has seen a change agent in macroscopic level. Then when the students write the net ionic equation students simply write a balanced equation back in this case means that students do not know that the net ionic equation only particles that change is written and ions that do not change are called spectator ions. Findings wrote ionic equation net is consistent with that found by Chandrasegaran (2007, p. 303) that the reaction of lead between the solution of lead (II) nitrate with potassium iodide solution 11% of students chose the answer that the ionic equation net is all the ions are present in the reactants and products.

Figure 3. Students Mental Model on Chemical Reaction Concepts Produce Gas

In profile mental model that emerged in the concept of chemical reactions that produce changes in temperature are students able to explain the reaction that produces the temperature changes at the level of the symbolic and the level of submicroscopic inconsistently and students are able to explain the reactions that produce temperature changes at the level of symbolic consistently and level of submicroscopic basis inconsistent. In Figure 4 below as much as 50% of students are able to write chemical symbol / formula chemical / molecular formula consistently NaOH, H2SO4, Na2SO4, H2O. However, students are not able to mention the particles (atoms, molecules, ions) that make up the reactants and a product (H2O composed of H+ and O2-). Not being able to explain the interaction between the particles and could not explain the net ionic equation. Being able to equalize the equation but can not prove that a balanced equation obey the Law Lavoisier.

In figure 5 is an example of the students’ answers as much as 50% of students are able to write chemical symbol / formula chemical / molecular formula consistently NaOH, H2SO4, Na2SO4, H2O. Able mention of particles (atoms, molecules, ions) that make up the reactants and the products with a consistent (Na+, SO42-, H+ and OH-). However, it is not able to explain the interaction between the particles and could not explain the net ionic equation. Being able to equalize the equation and could prove that a balanced equation obey the Law Lavoisier.
Write down the chemical symbol / formula chemical / molecular formula

\[ \text{NaOH (aq) + H}_2\text{SO}_4 (aq) \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O} \]

The particles in the reactants and products

Particles that interact to produce a product

Write down the net ionic equation

\[ 2\text{NaOH (aq) + H}_2\text{SO}_4 (aq) \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O} \]

Chemical equations obey the Law Lavoisier

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**Figure 4.** Students Mental Model on Chemical Reaction Concepts Generating Temperature Changes

**Figure 5.** Mental Model Students on Chemical Reaction Concepts Generating Temperature Changes
In profile mental model that emerged in the concept of a chemical reaction that produces a color change is that students are able to explain the reaction that produces a color change at the level of the symbolic and the level of submicroscopic inconsistently and students are able to explain the reaction that produces a color change on the level of symbolic consistently and level of submicroscopic basis inconsistent. In Figure 6, 30% students write the chemical symbols/ formulas chemical / molecular formula is inconsistent (Pb2(NO3)2). Able mention of particles (atoms, molecules, ions) that make up the reactants and the products are not consistent (NO3-). Not being able to explain the interaction between the particles and could not explain the net ionic equation. Being able to equalize the equation but could not demonstrate that chemical equations obey the Law Lavoisier.

Write down the chemical symbol / formula chemical / molecular formula

The particles in the reactants and products

\[ \text{Pb}^{2+} + 2\text{NO}_3^- \rightarrow \text{Pb(NO}_3\text{)}_2 \]

Particles that interact to produce a product

\[ \text{Pb}^{2+} + 2\text{NO}_3^- \rightarrow \text{Pb(NO}_3\text{)}_2 \]

Write down the net ionic equation

\[ \text{Pb}^{2+} + 2\text{NO}_3^- \rightarrow \text{Pb(NO}_3\text{)}_2 \]

Chemical equations obey the Law Lavoisier

Figure 6. Students Mental Model on Chemical Reaction Concepts Producing Color Change

Write down the chemical symbol / formula chemical / molecular formula

The particles in the reactants and products

\[ \text{Pb}^{2+} + 2\text{NO}_3^- \rightarrow \text{Pb(NO}_3\text{)}_2 \]

Particles that interact to produce a product

\[ \text{Pb}^{2+} + 2\text{NO}_3^- \rightarrow \text{Pb(NO}_3\text{)}_2 \]

Write down the net ionic equation

\[ \text{Pb}^{2+} + 2\text{NO}_3^- \rightarrow \text{Pb(NO}_3\text{)}_2 \]

Chemical equations obey the Law Lavoisier

Figure 7. Students Mental Model on Chemical Reaction Concepts Producing Color Change
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Figure 7 is an example of student answers as much as 70%, the student is able to write chemical symbol / formula chemical / molecular formula consistently (PbI₂, KI, Pb(NO₃)₂, and KNO₃), able to mention particles (atoms, molecules, ions) that make up the reactants and the products consistently. Not being able to explain the interaction between the particles and could not explain the net ionic equation. By understanding the symbolic level consistently students were able to equalize the equation and could prove that a balanced equation obey the Law Lavoisier.

Write down the chemical symbol / formula chemical / molecular formula

\[ \text{Na}_2\text{CO}_3 + \text{CaCl}_2 \rightarrow \text{NaCl}_2 + \text{CaCO}_3 \]

The particles in the reactants and products

\[ \text{Na}^+ \text{Cl}^- + \text{Ca}^{2+} \text{CO}_3^- \rightarrow \text{Na}^+ \text{Cl}^- + \text{Ca}^{2+} \text{CO}_3^- \]

Particles that interact to produce a product

\[ \text{Na}^+ \text{Cl}^- \text{Ca}^{2+} \text{CO}_3^- \text{NaCl}_2 + \text{CaCO}_3 \]

Write down the net ionic equation

\[ \text{Na}_2\text{CO}_3 + \text{CaCl}_2 \rightarrow \text{NaCl}_2 + \text{CaCO}_3 \]

Chemical equations obey the Law Lavoisier

\[ \text{Na}_2\text{CO}_3 + \text{CaCl}_2 \rightarrow \text{NaCl}_2 + \text{CaCO}_3 \]

Figure 8. Students Mental Model on Chemical Reactions Concept Produces Precipitate

The profile of mental models appearing on the concept of chemical reactions that produce sludge is students are not able to explain the reactions that produce precipitate either at the level of symbolic and submicroscopic level and students are able to explain the reactions that produce sediment at the level of symbolic and submicroscopic level inconsistently. In the figure 8 above is an example of the students’ answers on the concept of reaction that produces sludge as much as 80% of students are not able to write the chemical symbols / formulas chemical / molecular formula (NaCO₃, CaCl, CaCO₃). At the time of writing down the symbols and the chemical formula is the result of research Zvi (in Wu, 2000, pp. 3) revealed that when students write symbols and formulas are used, such as (s), H₂O(l), and Cl₂(g) students confused distinguish between atoms in the molecule. Then many of the students, after studying chemistry does not understand the role of chemical formulas and
some think that formula is just an abbreviation for the name is not a short way to represent the composition or structure, another misconception they consider chemical formula stands for mixed. PMM subsequently unable to name the charge correctly every-species (atoms, molecules, ions) constituting the reactant and product (Ca²⁺, CO₃⁻). Not being able to explain the interaction between the particles and could not explain the net ionic equation. This causes the students are not able to equalize the equation and cannot show that the chemical equations obey the Law Lavoisier.

In figure 9 above are examples of students’ answers on the concept of reaction that produces sludge as much as 20% of students are able to write chemical symbol / formula chemical / molecular formula but not consistently (Na₂CO₃, CaCl₂, CaCO₃, and NaCl). Able mention of particles (atoms, molecules, ions) that make up the reactants and products is inconsistent. Not being able to explain the interaction between the particles and could not explain the net ionic equation. Being able to equalize the equation and cannot prove that a balanced equation obey the Law Lavoisier. Yitbarek (2011, p. 11) argues that in the equation equalizes then they should write down the formula of the reactants and products, and indicates the relative number of particles of each of the reactants and products. It is also important to note that in chemical reactions atoms cannot be created or destroyed. In other words, the amount of each type of atom on the product side and on the side of the reactants must be the same arrow. Thus, the chemical equation must obey the Law Lavoisier.

5. Conclusion

Profile students’ mental models are revealed using Diagnostic Tests Mental Model-Prediction, Observation, explanation (TDM-POE) showed that most students have a mental model profiles that are not intact on the concept of chemical reactions. Students are only able to explain the reaction at the level of symbolic and submicroscopic level inconsistently and students are able to explain the reaction at a symbolic level consistently and submicroscopic level inconsistently. In fact, there are students who are not able to explain the reaction both at the level of symbolic and submicroscopic level. This becomes the input as important information for teachers to improve learning in the classroom.

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